CARBON DIOXIDE AND CLIMATE: THE GREENHOUSE EFFECT

HEARING

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT

AND THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

OF THE

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CARBON DIOXIDE AND CLIMATE: THE GREENHOUSE EFFECT

FRIDAY, JULY 31, 1981

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT, AND SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT,

Washington, D.C.

The subcommittees met, pursuant to notice, at 9:30 a.m., in room 2325 Rayburn House Office Building, Hon. James H. Scheuer (chairman of the Subcommittee on Natural Resources, Agriculture Research and Environment) presiding.

Mr. SCHEUER. This joint hearing of two subcommittees of the Science and Technology Committee will come to order. The Subcommittee on Natural Resources, Agricultural Research and Environment, which I chair, and the Subcommittee on Oversight and Investigations, chaired by my distinguished colleague Al Gore, have called this hearing. Also playing a very active role was Congressman George Brown, who was chairman in the last session of Congress of the Science, Research and Technology Subcommittee. The three of us have organized this set of hearings on the relationship of carbon dioxide and climate with emphasis on the "greenhouse effect." We are very happy to have this very distinguished set of witnesses and the panel that follows them.

I am not going to make a long statement. I am going to put a statement in the record.

[The opening statement of Mr. Scheuer follows:]

OPENING STATEMENT OF HON. JAMES H. SCHEUER

This joint hearing of the Subcommittee on Natural Resources, Agriculture Research and Environment and the Subcommittee on Investigations and Oversight will come to order.

Today we will examine the evidence of the potential impact on the environment from the increasing levels of carbon dioxide in the atmosphere.

For years the scientific community has expressed concern that the increased carbon dioxide may trap solar radiation, which can lead to a general global warming.

This phenomenon has come to be known as the "greenhouse effect." The dimentions and nature of the problem are, as yet, not fully understood. However, the potential impact on the environment is staggering.

It has been theorized that global warming could result in significant future changes in weather and climate patterns around the world.

Effects which have been projected for the United States include a warmer and drier climate in the grain-producing areas of the Midwest, with a consequent decrease in productivity.

Some studies have projected a loss of arable land as a direct impact of climate change, and a threat of flooding and perhaps even loss of some coastal areas due to warming of polar regions and thinning of polar ice caps.

In today's hearing we will examine the existing level of knowledge concerning the potential impact of increased levels of carbon dioxide and the current and future research in this area. The Federal research efforts are currently conducted under the lead of the Department of Energy.

The program developed by DOE is described in the January, 1981 publication, "Research Issues and Supporting Research of the National Program on Carbon Dioxide, Environment and Society." There have been indications that this program is undergoing a significant change in emphasis.

In our hearing today we will address that issue and expect that DOE representatives will provide a full disclosure of any proposed change in the content of that program, as well as proposals to limit or terminate research into any issue which had previously been a part of the research program agenda. In addition to officials from DOE, we will hear from witnesses representing other Government offices with responsibility in this area for policy and planning.

We will also receive testimony from a distinguished group of scientists, each of whom are knowledgeable on the issue of carbon dioxide buildup in the atmosphere.

Mr. SCHEUER. Clearly, the greenhouse effect is one of the major global phenomena that threaten to impact this planet of ours in the next few decades and certainly in the next century, in ways that are known and provable, and in ways the implications of which aren't yet known. It is one of the truly massive environmental threats that we have detected so far.

I am very glad that my two colleagues are Renaissance characters who function comfortably and intelligently and thoughtfully in the global environment.

Having said that, let me yield to my colleague Mr. Gore, and then to my colleague Mr. Brown. We are expecting our colleague from Pennsylvania and then we will get to the witnesses promptly.

Mr. GORE. Thank you, Mr. Chairman.

Mr. SCHEUER. I would ask unanimous consent to revise and extend my remarks at this point. There being no objection, it is so ordered.

Mr. GORE. Thank you, Mr. Chairman. It is a pleasure to work with you again on this subject.

It is difficult to come to grips with this issue. Quite frankly, my first reaction to it several years ago was one of disbelief. Since then I have been waiting patiently for it to go away, but it has not gone away. The evidence continues to indicate that this Nation may be on the way to a natural disaster of unprecedented proportions.

The increasing concentration of carbon dioxide in the atmosphere, commonly called the greenhouse effect, has the potential to radically alter our climate, upset our agriculture, and change the economic base of our society in fundamental ways. Ironically, though the Greeks might call it the result of our civilization's hubris, it appears that this effect is caused by the flowering of our industrial society.

In a very direct way we may be heading for a clash between human desires and the forces of nature, a clash that will finally require us to come to grips with the interaction between ourselves and the environment. But we are not helpless. There is still time to understand the implications of this change in our atmosphere and still time to make the kinds of energy choices that could forestall energy problems. At the most basic level, we need to understand more completely the effect of carbon dioxide creep in the atmosphere.

At this point I would like to illustrate my statement with a chart which I asked our subcommittee staff to reproduce, which shows

the impressive nature of the data which has been gathered. I would ask unanimous consent that the middle chart which we have displayed be included in the record at this point.

[The information follows:]

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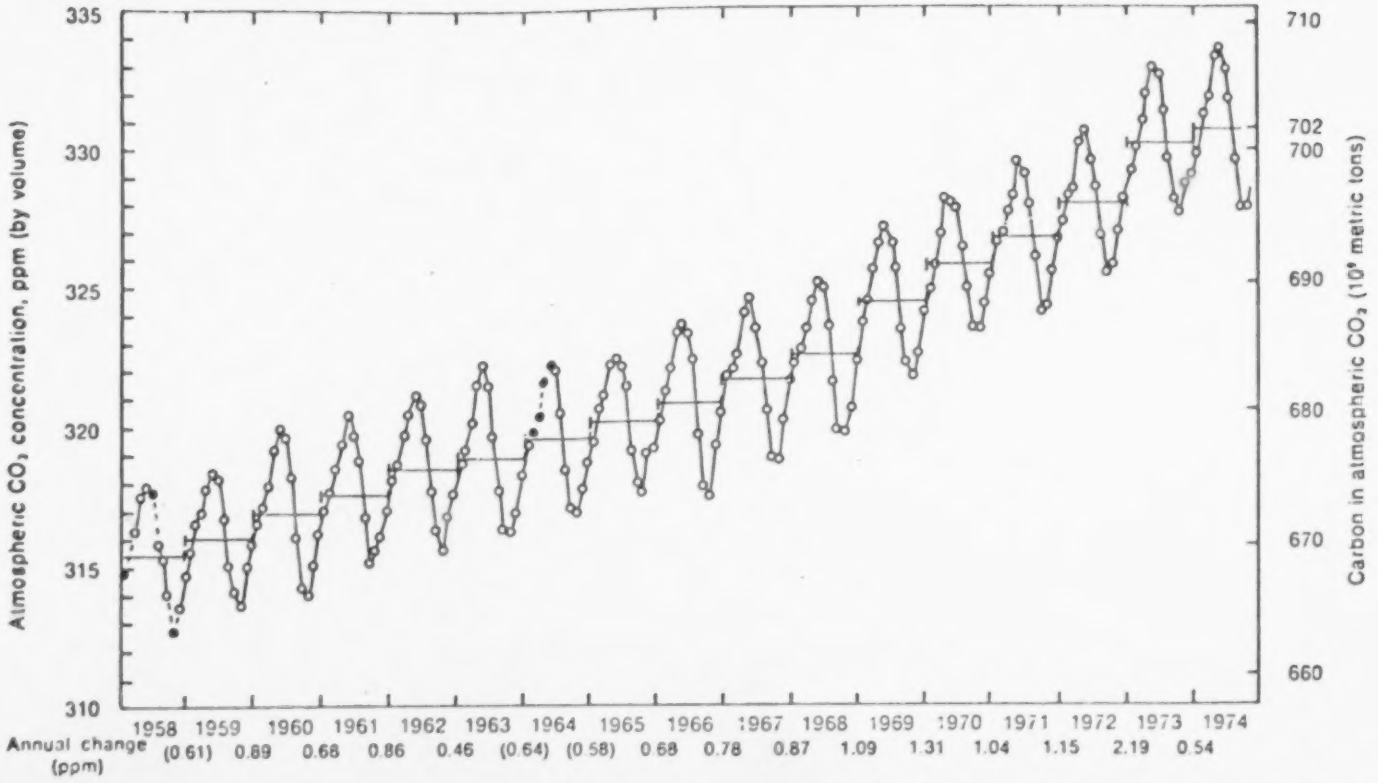

Figure 2. Monthly average values of the concentration of CO_2 in the atmosphere at Mauna Loa Observatory, Hawaii, are plotted since the beginning of accurate and regular measurements in 1958. A few of the annual changes are enclosed in parentheses because they include interpolated points, shown as dots. Variations in photosynthesis and other seasonal effects produce the annual cycle. Mean annual concentrations are well above the preindustrial level (290–300 ppm), and the secular increase is quite apparent. (1958–1971 data from Keeling et al. 1976; later data by pers. comm. from Keeling.)

Mr. GORE. I was operating on the assumption that the evidence was of at least a marginally questionable nature. But as that chart indicates, the scientific observations have been very, very thorough. And if you look closely at the peak points of each annual cycle, you will see that the recession of 1974 and 1975 is clearly indicated in the measurements of carbon dioxide concentrations in the upper atmosphere out in the middle of the Pacific Ocean. The connection then between the burning of fossil fuels by our industrial society and the increasing concentration of carbon dioxide in the upper atmosphere would seem to be quite obvious.

If we are going to face this problem, we are going to ask a number of questions and insist upon thorough answers and complete answers to them.

First of all, how much carbon dioxide do we expect to put into the atmosphere in the future?

Second, what will happen to the carbon dioxide "sinks"? Will the oceans be able to take in more carbon dioxide as more is put into the atmosphere or will we reach an abrupt limit? As the concentrations increase, will the oceans take in less carbon dioxide?

Third, what other effects are at work on our climate besides the concentrations of carbon dioxide that might exacerbate or lessen the potential problems with which it is associated?

Fourth, what beneficial as well as what harmful effects might we see?

I might add there, from a nationalistic point of view, it is of little comfort if the world as a whole has good effects and bad effects, but the bad effects are concentrated in nations sharing the latitudes that we share. If our grain belt is moved to Canada, that may be fine, on the average, looking at it from the point of view of both the United States and Canada, but it is not too pleasant looked at from the point of view of the United States alone.

What kind of technology like genetic engineering might we use to divert the worst effects?

While we are still uncertain about the answers to these questions, we must do the work now that will insure that we can handle the problems that we have created. As a science committee, we would be failing in our responsibility to the people of this Nation if we did not take this quintessential policy problem seriously.

Many of our witnesses today are from the academic environment. But the greenhouse effect is not merely an academic question. The paths we take today I hope will help us determine whether we have disasters or merely manageable problems in our future.

Thank you.

Mr. SCHEUER. Thank you very much.

Now my colleague from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

I do not have a formal opening statement, but I would like to congratulate both you and the chairman of the Investigations and Oversight Subcommittee for holding these hearings.

I think we have become more and more aware over the years of the risks that are associated with energy production of all kinds. This hearing will serve to demonstrate that the production of fossil fuels in our society carries with it perhaps some inherent risk, as

well, and that we need to examine all of these things in order that our energy future is balanced by what we regard as acceptable and unacceptable risks. And I think that this hearing will serve to provide some focus on this aspect of a problem not only for the present but certainly for the future.

In addition, Mr. Chairman, I would ask that Mr. Carney, the ranking Republican member on your subcommittee, be permitted to file an opening statement immediately following mine later for the record.

Mr. SCHEUER. We have already had permission for all members to revise and extend their remarks before the witnesses.

[The opening statement of Mr. Carney follows:]

OPENING STATEMENT BY CONGRESSMAN WILLIAM CARNEY

Thank you, Mr. Chairman. As in the case of our recently planned hearing on acid rain, you have again chosen a hearing subject that represents a problem of global proportions, yet one for which the nature of the problem and the necessary solutions are not well understood. I again have the feeling that we had better do something and perhaps do it quickly, but I am not sure just what it is that needs to be done. That, of course, is why we are having this hearing.

The potential impact of higher carbon dioxide levels in the atmosphere is something we know a moderate amount about in a qualitative sense, but need to know much, much more about quantitatively. What we do know has already been summarized by one of our witnesses, generally as follows: (1) the problem is global, (2) it is one the scope of which we have not yet experienced, (3) it is long range, (4) it is closely related to the global energy problem, (5) the role of the less-developed countries will be essential to solving or increasing the problem, as it is those countries who, through their decisions on future burning of fossil fuels, will tip the balance one way or the other, (6) international agreements on actions to abate the problem will be difficult to obtain, (7) quantitative estimates of costs and benefits are not now possible to obtain, and (8) the range of possible outcomes of the problem can be estimated.

One point that is often overlooked in carbon dioxide discussions is that of the relationship between decisions we make now and the atmospheric situation 20, 30 or 40 years from now. There are those who believe that it is not until well after the turn of the century that CO_2 levels may reach "critical" levels (whatever they might be). However, it is the actions we take now with regard to our energy program, and the decisions we make now with regard to how much nuclear, how much fossil, and how much solar energy we will employ in future years, that will determine the atmospheric levels of carbon dioxide in those years.

If we err on the side of too much fossil fuel and too much carbon dioxide, the environmental consequences may be substantial. On the other hand, if we overreact and, for example, require overly stringent pollution protection equipment, the situation may be just as catastrophic in an economic sense. According to one study, adherence to a relatively severe environmental protection policy would cost U.S. consumers a total of $5.2 trillion over the next 25 years. This would involve more than just protection against CO_2 buildup, but the issue is clear. We must know where we stand on this issue, and what we need to do—and not do.

One of the reasons why we are holding this hearing, as the Chairman has indicated, is to determine where the emphasis is in the Department of Energy's program on carbon dioxide. These are several questions that the Department has been looking at, including how much can CO_2 levels increase before the temperature increase becomes significant, whether increasing temperatures pose serious problems, and whether anything can be done to reverse the trend toward more CO_2 in the air. I personally feel the last question is the most critical, and would ask our witnesses to comment as to whether they agree or disagree with that assumption.

Mr. Chairman, that concludes my opening remarks. I welcome the witnesses, and am looking forward to their testimony.

Mr. SCHEUER. Let me say, Congressman Walker was the ranking majority member on the DISPAC Subcommittee that I chaired in the 95th Congress.

Mr. WALKER. It goes back at least that far.

Mr. SCHEUER. He was a thoughtful and contributing member and we very much value his participation in the hearings and in the work of the full committee. I must say that Congressman Carney is also a superb ranking minority member who has been of inestimable support in all aspects of the committee's work.

Congressman George Brown?

Mr. BROWN. Thank you.

I would like to commend you and Chairman Gore for the hearings and for assembling what I immediately recognize to be probably the most knowledgeable panel that you could have assembled from any place in the country.

I know that all of these gentlemen have been involved in research and policy analysis of this problem for a large number of years and we are fortunate to have them before us this morning.

Mr. SCHEUER. Our first witness in this panel will be the very distinguished Prof. Roger Revelle, program in science, technology, and public affairs, University of California in San Diego.

Mr. BROWN. I do not know what the message is going to be from Professor Revelle. I do know that several years ago when we had the hearings of the Select Committee on Population, which I had the honor and pleasure to chair, Roger Revelle gave us enormously helpful testimony in the field of population and development; again he took us to the mountaintop and gave us a world overview that was enormously thoughtful and stimulating, and we are sure he will do the same thing again today.

Mr. GORE. Mr. Chairman, if I may make a point of personal privilege, I would like to also welcome Professor Revelle as a former student. I took your course at Harvard on population studies and it was one of the best I have ever taken. You have been a pioneer in more than one field, and it is a great pleasure to see you here on this occasion.

STATEMENT OF ROGER REVELLE, PROGRAM IN SCIENCE, TECHNOLOGY, AND PUBLIC AFFAIRS, UNIVERSITY OF CALIFORNIA, SAN DIEGO

Mr. SCHEUER. You have just passed the acid test of approbation by your students.

Your statement and the statements of all of the witnesses will be printed in full. So you might chat with us for 10 or 15 minutes informally, highlighting your testimony.

Mr. REVELLE. What I thought I might do first is to try to give some kind of a general framework for this hearing.

Mr. SCHEUER. Excellent. Are you going to talk from the charts?

Mr. REVELLE. Yes, if I may. A good case can be made for saying that the most important substance in the world is carbon dioxide, for several reasons. In the first place the carbon in the carbon dioxide is what makes all plant life and all animal life possible. We consist very largely of carbon which comes to us by way of the photosynthesis of plants, which, in turn, get their carbon out of the carbon dioxide of the air.

The second reason is that if there were no photosynthesis and carbon dioxide we wouldn't have any oxygen in the atmosphere. The oxygen has come very largely, perhaps almost entirely, from the breakdown of carbon dioxide by plants and the burial of the

carbon in deep sea sediments, with the oxygen remaining in the air.

The third reason, which is the one that we are particularly concerned with today, is that the presence of carbon dioxide in the atmosphere makes the Earth livable. We have liquid water on the Earth because the average temperature is high enough. If there were no carbon dioxide in the air, it is very likely that all water would be frozen, there wouldn't be any liquid water; the average temperature of the Earth would be well below the freezing point. So carbon dioxide is an essential component of the atmosphere which allows everything else we are concerned about to exist.

There probably have been fluctuations in the carbon dioxide in the atmosphere over geologic time which have caused variations in climate. For example, one of the major contributing factors to the world temperatures of the ice age, the glacial age, was very likely that the carbon dioxide content of the air went down to about two-thirds of the value that it has now. This was certainly not the only reason for the ice age but it may have made a major contribution to the low temperatures that prevailed at that time. In earlier times, 40 million years or so ago, the much higher average temperatures at high latitudes may also have been due to higher carbon dioxide in the air.

So much for a general picture of the relationship between carbon dioxide and climate. This is very speculative as far as past variations in climate are concerned, but not at all speculative about the overall effect, which is that atmospheric temperatures are 15° to 25° higher, than they would be in the absence of any carbon dioxide in the air.

Nearly 100 years ago, the great Swedish scientist, Svante Arrhenius, and the American geologist, Thomas C. Chamberlain, pointed out that because of the burning of coal and later oil—they were not so familiar with oil but they were familiar with coal—the added carbon dioxide in the air might raise the average Earth temperature.

This idea seemed to become more realistic during the 1930s and the 1940s, because the average temperature of the atmosphere was observed to be increasing. One of the major projects of the International Geophysical Year in 1957–58 became an attempt to actually measure the atmospheric carbon dioxide. A man named Charles David Keeling, of the Scripps Institution of Oceanography, set up two monitoring stations, one on the top of Mauna Loa and one at the South Pole.

Keeling is a quite remarkable person. Except for his keen interest in music has thought about nothing but carbon dioxide for the last 25 years. He is extremely careful, extremely meticulous, and very expensive.

I remember when I was director of the Scripps Institution, I managed to raise enough money for him to get started on his two measuring stations at the South Pole and the top of Mauna Loa, but we never had enough money. It always took twice as much money as he budgeted for. Nevertheless he managed, by sheer persistence and guts and making a nuisance of himself, to make these extremely accurate measurements, and they have been con-

tinued now on Mauna Loa and at the South Pole for nearly 25 years.

The result is given on this graph here which shows two things:

One, you will notice the annual fluctuations. Those are due to the fluctuations of photosynthesis between summer and winter in the Northern Hemisphere. During the summer in the Northern Hemisphere, plants work hard and capture a lot of carbon dioxide and turn the carbon into their own tissues.

During the winter the plants don't work so hard and a lot of that carbon is oxidized back to carbon dioxide. So the winter values are several parts per million higher than the summer values. The same annual fluctuation occurs at the South Pole but it is very much smaller because there is much less photosynthetic activity in the Southern Hemisphere.

The other thing you will notice is a continuous rise. It isn't an absolutely straight line, it is a wiggly line, and the wiggles are not really very well understood. I would like to think that the 1974 wiggle was due to the recession, and maybe it was, but there are possible natural phenomena that explain it too.

But in spite of the slight wiggles, the simple fact of the case is that during this 25-year period the carbon dioxide content of the air has increased between 6 and 7 percent and it is increasing more rapidly every year.

If we look at the entire history of the atmosphere since the beginning of modern industry, about 1850, the carbon dioxide content has probably increased about 13 percent.

What we are worried about is that in the future it may increase much more and much more rapidly as the use of fossil fuels, coal and oil and natural gas, increase; perhaps oil shale and oil tar sands also.

So far the climate has not responded in a measurable way to this increased carbon dioxide. The way scientists would put it is that the noise level is too high. The noise is the variation of three-tenths or four-tenths of 1° C from year to year in world average air temperature. This masks whatever carbon dioxide effect there may be.

One of the important problems from the scientific point of view is to find an early warning signal, to find something that is happening in the atmosphere which will show that the models, and the projections of increased average temperature, are correct.

Another problem is to find out how much of the carbon dioxide will remain in the air. If we ask ourselves how much oil and coal and natural gas were burned during this 23-year period, it is about twice the amount of carbon remaining in the air; in other words, the airborne fraction, as it is called, is only about half what it would be if all the carbon dioxide produced by the burning of fossil fuels had remained in the air.

Where is our carbon dioxide? Something has been getting it. What has been getting it is probably partly the biosphere; that is, plants have been taking up some of its added carbon dioxide, but more important probably is the take-up by the ocean. It is generally thought that perhaps 40 percent of the carbon dioxide produced has been absorbed in the ocean.

As time goes on, nearly all of the added carbon dioxide will go into the ocean but that will take quite a long time, maybe as much as 1,000 years. So we are faced then with a possible climate change over the next century and over centuries to come that will last for much longer than the probable lifetime of all of the world's fossil fuels.

Putting this in quantitative terms, at the present time there are about 700 billion tons of carbon in the atmosphere. That could be doubled perhaps within the next 75 years by the burning of coal and oil and natural gas.

Nowadays, from the burning of fossil fuel, we produce about 5 or 6 billion tons of carbon a year as carbon dioxide. This rate of production is liable to increase. As the poor countries of the Earth develop economically and socially, they will have to use a lot more energy and the principal source of energy on a worldwide basis now and for a long time to come is likely to be coal and oil and natural gas.

Such things as the making of synthetic liquid fuels out of coal will increase the rate at which carbon dioxide is added to the air. The best fuel to use from the standpoint of the amount of energy you get per ton of carbon is natural gas.

Many experts believe that there is plenty of natural gas. Consequently, one of the sort of major projects, it seems to me, that nations should undertake is to find and use a lot more natural gas, in order to slow down its rate of emission of carbon dioxide.

Now, Mr. Chairman, if I may I would like to go back to my seat and talk a bit about the kinds of research that are needed.

Mr. SCHEUER. Although it may be true that, of the fuels you have mentioned, gas may be less damaging environmentally from the standpoint of carbon dioxide, doesn't this also emphasize the importance of achieving nonfuel sources of energy: tidal, wind.

Mr. GORE. Nuclear.

Mr. REVELLE. Yes. Nuclear is No. 1, perhaps, but biomass is also a major possibility. It would be possible to produce all the energy that the world uses now from less than a quarter of the forested area of the Earth.

Mr. SCHEUER. You are advocating cutting down our forests?

Mr. REVELLE. I am advocating that we husband our forests by planting them just like farmers plant corn, having forest plantations.

Let me just cover in a general way the kinds of research that I think are very important for us to understand this problem and to understand its implications for human beings.

The first one is the problem of risk: What are the risks, can we assess the risks and can we balance these against possible benefits?

There are several possible kinds of risks. Perhaps the most worrisome is the possible disappearance of the west Antarctic icecap. We are almost certain that the west Antarctic icecap did disappear in the last glacial period about 125,000 years ago. Many people think it is unstable enough so that it might disappear again with a rise in the average air temperature by 3° or 4° C.

Mr. SCHEUER. Just to clarify, it disappeared, and you say it might disappear again. The assumption is that it gradually came back?

Mr. REVELLE. Yes, it did, apparently. Obviously it is there now. The reason we think it wasn't there during the last ice age is that in many places on the Earth there is a terrace about 5 meters above existing sea level. These terraces have been dated by various kinds of radioactivity techniques, and the dates all cluster around 125,000 years.

Another piece of evidence which I do not know how to evaluate is that the sea level seems to have been rising lately faster and faster. Forty years ago the sea level was rising on the average about 1 millimeter per year. According to Professor Emery at Woods Hole, sea level during the last 10 years has been rising at about 1 centimeter a year, 10 times as fast.

The only possible way that this can occur is by melting of ice, and the addition of the melted water to the ocean.

Mr. Etkins, who is in the audience, and his colleague Ed Epstein, have written a paper that demonstrates this quite beautifully.

If the Antarctic icecap, is going to disappear again, we must ask ourselves how rapidly this will happen. This is a question for a good deal of glaciological study.

A second phenomenon which may create equal difficulties is the possible disappearance of the Arctic Sea ice. The Arctic has been covered with ice so far as we know during and since the last ice age. This thin scum of ice over the Arctic has a profound effect on climate. It could conceivably disappear with the rise in average air temperature, which would probably be much greater at higher latitudes.

The third possible risk is the melting of the permafrost in the northern lands.

As you all know, great areas in high latitudes are covered with frozen ground called permafrost. Whenever this permafrost melts, the previously frozen ground becomes a very messy material to work with. More serious, from the carbon dioxide standpoint, is that the permafrost contains a good deal of peat, and the peat might oxidize if the temperatures go above freezing. Also, it contains a good deal of methane, in a form called methane hydrate, frozen in with the water. If the permafrost melts, the methane might escape and add a good deal of carbon to the atmosphere.

There are other possible risk effects. One I am inclined to think is most serious is that if we have an increase in average temperature by 4° or 5° C at the latitudes of the United States, we might have much hotter summers whenever there was a climatic excursion from the average; that is, the extreme summer temperatures might be a good deal higher than they are now. There is some reason to believe that this would have a serious effect on many elderly people and people who are susceptible to extreme temperatures.

The National Oceanic and Atmospheric Administration thinks about 2,000 people died who would not have died otherwise, because of the high temperatures experienced in the summer of 1980. If summer temperatures go up by another 10° F above what they were then, that might be a serious matter.

Two other things are important. One of them is that there may be beneficial effects of additional carbon dioxide. Our problem is really to take advantage of these effects.

Carbon dioxide is a fertilizer, it is one of the substances that limit plant growth. If you have enough nitrogen, enough water, enough phosphate and enough sunshine, then plants are limited in their growth by the amount of carbon dioxide in the air.

So if we increase the atmospheric carbon dioxide, what might happen is that we will get higher yielding crops. The problem is to take advantage of this phenomenon by increasing the plant products that do us some good. The things that we eat, in wheat, corn, rice, potatoes, and other staple foods, are plant seeds. What we need to do is to teach plants by genetic manipulation to produce more seed if they produce more photosynthetic product.

I think it is a tremendously important and a tremendously interesting research problem and possibilities are very great.

One of the major problems with crop plants, in fact all plants, is that they are subject to stresses of various kinds. One of the stresses that they are subject to is water shortage; another stress is high temperature.

Hence, a second major problem is to develop crop plants by research which will be resistant to water stress and temperature stress.

In the case of animal husbandry, the same general problem exists. Most livestock are produced at latitudes corresponding to that in the northern part of the United States. Here we expect temperature to rise perhaps as much, on the average, as 6° C if atmospheric carbon dioxide is doubled. We know that cattle, chickens, and other livestock don't produce as well, eat as well, don't get as fat, don't grow as well when the temperatures are too high. Again the problem is a research problem, to find breeds and varieties of livestock which will be resistant to higher temperatures.

I have spoken already about the fact that one of the major sources of energy that doesn't involve fossil fuels is biomass, particularly in the biomass in trees. We need to find fast-growing trees that will grow faster under conditions of increased carbon dioxide.

The effects of a climatic change might be much more drastic for the less-developed countries, for the poor countries, than for the United States, simply because their societies are so much less resilient, so much less able to cope with stresses of any kind.

One of the major practical research problems here is to find ways for better use of water, better water management in countries like Pakistan, India, the African countries, which are often water short. At the present time the efficiency of irrigation is only about 25 percent; that is, only about 25 percent of the water used in irrigation actually does any good to the crops. That could probably be raised to about 50 percent by better understanding of how to use water.

I will skip over the research on societal and institutional responses because I think Dr. Lave will be able to handle that very well. But I do want to talk about one very important problem which is both socioeconomic and environmental and that is the problem of changes in river flow.

In the United States the river that we westerners are most concerned about is the Colorado River. The existence of the West to a very large extent depends upon the use of the Colorado River water and its tributaries.

I have given a table on page 8 of my testimony, Mr. Chairman, on which I show that at 40° north latitude precipitation might decrease by as much as 14 percent and temperatures might increase by as much as 6° C. These are projections made by Herman Flohn, a great German climatologist.

The table points out that there are two places, one at about 40° north latitude, the other about 10° south latitude where there would be, according to his computations and modeling, a very marked reduction in precipitation.

The flow of a river depends not on precipitation but on the difference between precipitation and evaporation. With higher temperatures you would have more evaporation and at 40° latitude less precipitation, according to the table.

The two things combined might cause as much as a 50-percent reduction in the flow of the Colorado River. The average flow, now about 15 million acre-feet per year, might go down to about 7 million acre-feet per year. This would have a profound effect on many activities in the West, including agriculture and even the production of oil from oil shale and the mining of coal, the strip mining of coal, because both those processes require quite a bit of water.

In other parts of the world, at this latitude of about 40°, which goes through Europe pretty close to Lisbon, Naples, Ankara, and Athens, the same kind of phenomenon, that is a great reduction in riverflow—the flow of the Po, for example, and of the Rhone—might occur because of the decrease in precipitation and increase in evaporation.

In China, the Hwang Ho would be subject to the same kind of change, and the basins of the Amur Darya and the Syr Darya, two of the major areas of irrigated agriculture in the Soviet Union might again have as much as a 50-percent fall in the river runoff and therefore very serious pressure on irrigation water supplies.

Now, this change in riverflow clearly is something that we can do something about now if we really take it seriously. This is by no means just an engineering problem, it is very much of a political and economic problem.

One thing we might have to do is to change the allocation of water from agriculture to other uses. Or we might have to introduce such things as interbasin transfers, for example, from the Northwest to the Colorado River watershed. Both these things are political issues that make people see red on both sides and we have to learn somehow to plan and to convince people that things like this need to be done and make them politically acceptable to do.

I think I have talked long enough, Mr. Chairman. I would be glad, however, to answer questions.

[The prepared statement of Mr. Revelle follows:]

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ENVIRONMENTAL AND SOCIO-ECONOMIC RESEARCH NEEDED FOR BETTER APPRAISAL OF THE CO_2 PROBLEM

Roger Revelle

University of California, San Diego
La Jolla, California 92093

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to

Subcommittee on Natural Resources and Agriculture Research and Environment
James H. Scheuer, Chairman

Subcommittee on Investigations and Oversight
Albert Gore, Jr., Chairman

COMMITTEE ON SCIENCE AND TECHNOLOGY
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ENVIRONMENTAL AND SOCIO-ECONOMIC RESEARCH NEEDED FOR BETTER APPRAISAL OF THE CO_2 PROBLEM

In adding CO_2 to the atmosphere, mankind is unintentionally conducting a great biological and geophysical experiment. This experiment can be expected to increase scientific understanding of ecological systems and of the processes in the ocean and the atmosphere that partially determine world climates. But from the standpoint of governments and peoples, the major problem to be solved is to understand the nature of the impacts on societies of rising levels of atmospheric CO_2, with the objective of avoiding or ameliorating unfavorable impacts and gaining most benefit from favorable impacts. Environmental and socio-economic research is necessary to provide the needed understanding. On the basis of this research, we should be able to make better qualitative estimates of the range of probable outcomes. Such estimates could be used to lay a rational groundwork for policies and actions which would change the rates at which costs and benefits are incurred and increase the likelihood that benefits will exceed costs.

I. THREE KINDS OF RESEARCH ARE NEEDED

Three kinds of research on the consequences of rising levels of atmospheric carbon dioxide and possible climatic change are called for:

A- Assessment of risks (and potential benefits) that could be averted only by limiting carbon dioxide emissions. This category includes possible changes of physical processes in the ocean and the cryosphere and effects on the biology of marine, freshwater, and terrestrial ecosystems in which effective human intervention is unlikely.

B- Research to enhance beneficial effects and lessen harmful ones, where this is possible, and to slow down rates of carbon dioxide emission.

C- Study of potential social and institutional responses to the consequences of higher atmospheric carbon dioxide and projected climatic changes.

A. RISK ASSESSMENT

1. Possible disappearance of the West Antarctic Ice Sheet. This portion of the Antarctic ice cap is believed by some glaciologists to be unstable. If there were a marked warming in polar regions, it might disappear, causing a worldwide rise in sea level that would inundate many coastal cities and much valuable agricultural land. We need to be able to estimate the probability that this event could occur and the approximate rate, that is, whether the time involved might be measured in decades or centuries. As an analog of possible future deglaciation, an attempt should be made to determine if the West Antarctic ice cap disappeared during the last Interglacial period, about 120,000 years ago. Better understanding is needed of the dynamics of the ice streams flowing from West Antarctica, the relationships of these streams to ice shelves, and the effects on the ice shelves of the disappearance of seasonal pack ice and of heating of the surrounding ocean waters.

2. Effects on Arctic Ocean Sea Ice. The Manabe-Weatherald model indicates that with a four-fold increase in atmospheric CO_2, the cover of sea ice over the Arctic Ocean would disappear, at least in the summer time, with possibly profound changes in oceanic and atmospheric circulation. To be able to estimate the likelihood of this event and the possible consequences, greater understanding is needed of the dynamics of formation and dissolution of sea ice in the Arctic Ocean and the surrounding seas and of the interactions between the sea ice and the underlying waters.

3. Melting of Permafrost in High Northern Latitudes. With a sufficient increase in atmospheric CO_2, climatic warming of 5-10°C. might occur over land in high latitudes. This could result in extensive thawing of permafrost, with marked effects on the hydrology and ecology of the tundra. These areas of frozen ground contain large reservoirs of organic carbon in peat deposits, and probably also in methane hydrates a few hundred feet below the surface. Thawing of the permafrost, caused by climatic warming from an atmospheric CO_2 increase, could result in oxidation of the peat and release of methane gas, and thus in a positive feedback effect on atmospheric carbon dioxide. The magnitude of this effect would depend on the size, location, and present temperature-depth relationships of the peat and methane hydrate deposits. Reconnaissance surveys should be made to determine these quantities. Scientific cooperation with Canada and the U.S.S.R. is necessary because of the vast areas of frozen ground within these countries.

4. Other Possible Effects Not Susceptible to Human Action. We are also concerned with those effects of increased atmospheric and climatic warming which, if they occurred, would be difficult or impossible to modify by deliberate human actions. We need to estimate the probability of occurrence of such effects, the approximate magnitude and timing of the deleterious (or beneficial) consequences, and the costs of societal adaptations to these consequences relative to the costs of stopping or drastically reducing the use of fossil fuels. Examples of such effects are the possible disappearance of the West Antarctic ice cap and of the Arctic Ocean sea ice, melting of permafrost in high northern latitudes, and the consequences for marine phytoplankton communities and coral reefs of a higher hydrogen ion concentration (lower pH) in near-surface ocean waters.

   Several questions of this kind relate to human health and behavior and to environmental conservation:

   a- What will be the effect of higher ambient CO_2 concentrations on human respiration and how will this - if it exists - affect human life expectancy?

   b- Given warmer average temperatures in mid-latitudes, will occasional very hot summers, resulting from inter-annual climatic variations, cause life-threatening stresses on physiologically-vulnerable groups in human populations and among domestic animals?

   c- How will the projected fall in upper atmospheric temperatures interact with additions of chlorofluoromethanes and other gases to alter the ozone content of the stratosphere? How will the resulting change in solar ultraviolet radiation reaching the earth's surface affect human beings and other organisms--terrestrial, aquatic, and marine?

   d- Will the rates of extinction of endangered species be accelerated by the expected climate changes, particularly species living near the upper limits of their temperature tolerance?

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B. RESEARCH TO ENHANCE BENEFICIAL EFFECTS AND LESSEN HARMFUL ONES

Far-reaching results can be hoped for from research of this kind applied to agriculture, forestry and animal husbandry, with the objectives of increasing productivity and attaining greater resiliency of agricultural systems under climatic change.

1. Biological Effects on Crop Plants of Increases in Atmospheric CO_2. One of the principal benefits of increased atmospheric CO_2 might be higher photosynthetic productivity and water-use efficiency in cultivated crops. Indeed, it is not impossible that a small part of the improvement in agricultural yields experienced during the past 50 years has resulted from the 13 percent increase in atmospheric CO_2 content since the 19th century. But much research is needed to take full advantage of expected future atmospheric CO_2 levels. Studies should be undertaken to determine whether varieties of field crops can be developed, through conventional breeding programs and modern methods of genetic manipulation, that will have higher net photosynthetic production and use less water as the atmospheric CO_2 content increases, but will not respond to a warmer atmospheric temperature by an increase in respiration that would cancel out the effect of CO_2 fertilization. We are concerned both with more total plant production and an increase of the "harvest index," that is, the portion of the plant that can be used by human beings for food, fuel, fiber, or other useful products. The effects of higher temperature and increased carbon dioxide on biological nitrogen fixation and on weeds, insects, and microbiological pests must be taken into account. Programs of genetic improvement should include greater resistance to pests, as well as to other environmental stresses.

2. Improved Stress Resistance in Crop Plants. The climatic changes that are likely to accompany rising levels of atmospheric carbon dioxide will produce environmental stresses in many crop plants, resulting from higher average and extreme temperatures, and possibly also from lower water availability, the presence of atmospheric pollutants, particularly oxidants, unfavorable soil nutrient levels, increased soil alkalinity, or higher soil salinity. Research aimed at alleviating these environmental stresses should proceed along three parallel lines:

   a- Studies of the basic biology of plant response and resistance to environmental stresses;

   b- Genetic manipulation of crop varieties for greater resistance to environmental stresses;

   c- Development of production-management systems that maximize the expression of genotypic stress resistance.

The objective should be to improve average yields over relatively long periods, during which interannual climatic variations can be expected to occur.

In developing stress-resistant crop varieties, advantage must be taken of a wide variety of plant germ plasm. This will require a major expansion of present programs to preserve existing gene pools of important plant species, particularly in the developing countries of tropical and subtropical regions. Three kinds of work are needed:

a- Systematic collection, preservation, description, evaluation, and cataloging of germ plasm of useful plant species;

b- Study of the requirements for long-term storage, viability, and preservation of variability;

c- Research on gene recombinations to develop plant materials adaptable to environmental change and human needs.

3. Effects on Managed Forests. Biomass energy from forest trees can be at least partly substituted for fossil fuels, particularly in the tropics and subtropics, but this substitution will be possible on a sustainable basis only if the productivity of forests can be greatly increased. Research on the effects of increased atmospheric CO_2 and higher temperatures on high-yielding trees of tropical and subtropical regions under different conditions of water stress should be given priority, particularly on species that possess symbiotic nitrogen-fixing bacterias such as Leucaena, Casuarina, Sesbania, and various species of Acacia. In the future, the rapidly-growing energy demands of tropical and subtropical developing countries might be met in large part by renewable biomass fuels from forest plantations, with a consequent reduction in worldwide CO_2 emissions.

4. Effects of Climate Change on Animal Husbandry. Meat, milk, eggs, and other animal products make up a large fraction of the world's agricultural output. The greatest concentrations of poultry and livestock production exist in the Temperate zones, where a rise in average temperatures of more than 4°C. could occur if atmospheric CO_2 is doubled. With presently-used animal varieties, nutrient intake and utilization and reproductive rates diminish with rising temperature, and the incidence of diseases may rise. Physiological research on metabolic and endocrine systems in domestic animals under conditions of high average temperature and occasional extremely hot seasons is needed to understand and quantify these effects. This should lead to improved management practices, including better dietary formulations, breeding periods synchronized with seasonal climate variations for most favorable conception and reproduction, low-cost animal shelters to buffer climatic changes, and selection of livestock and poultry varieties best suited to

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higher average and extreme temperatures. Attention should also be given to changes in the species composition of forage plants in grazing lands and cultivated pastures that could give higher nutrient concentrations.

In tropical and subtropical regions, the rise in average temperatures is expected to be relatively small, within the adaptive range of existing domestic animal varieties. But changes in precipitation regimes toward both more moisture in some regions and greater aridity in others will require adaptive research on animal feeding systems from range lands, seeded pastures, cultivated forages, crop residues, and trees. Probable geographical shifts of disease and pest zones, following changes in the location of climatic zones, call for intensified research on prevention and control.

5. Better Management of Water Resources in Developing-Country Agriculture. The traditional agricultural systems of many developing countries will be especially vulnerable in regions where increased aridity results from carbon dioxide-induced climatic change. Capital investments in large irrigation systems will often be necessary, but improvements in management of irrigation water, based on site-specific applied research, could be even more important. Dependability of irrigation supplies is essential. In many river basins, this can be attained by conjunctive use of surface and ground waters. The greatest gains can be expected from improvements in on-farm water management. More than a doubling of the efficiency of use of irrigation water can be looked for, from less than 25% to more than 50%, by reducing losses in conveyance systems, controlling depth and uniformity of water applications, lessening evaporation losses, using simple methods for water measurement, and better timing of irrigations. Changes in cropping patterns, times of planting, and area planted will also often be desirable or necessary.

C. RESEARCH ON SOCIETAL AND INSTITUTIONAL RESPONSES

1. Construction of Scenarios. Because of the important feedbacks among atmospheric and ocean dynamics, marine and land biota, and agriculture and energy use, the global CO_2 problem can best be defined by constructing integrated simulation models - that is, scenarios. A range of scenarios created by teams of physical, biological and social scientists working together could constitute a framework for viewing the complex implications of the problem. These scenarios would have three major components:

   a- A set of initial conditions, including the projections of world rates of energy use and carbon dioxide emissions discussed above;

   b- Cause-and-effect models that relate these initial conditions and perturbing forces (such as specific climatic changes) to outcomes; and

   c- Analyses of the implications of these outcomes.

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The objective should be to create plausible and internally-consistent combinations of assumptions and estimates about regional climates, ocean and ice dynamics, changes in marine and land biota, effects on agriculture, and societal responses. One part of these scenarios would be models of future international behavior and institutions that might result from the perceived self-interests of different nations. Uncertainties must be modelled explicitly, with the aim of estimating the optimum flexibility and resiliency that societies will need in order to deal with uncertainties at the lowest practicable cost. The process of scenario construction should be iterative, with each round aimed at greater consistency and sharper definition of unanswered questions. By integrating available scientific information, scenarios can serve as powerful guides to further research.

2. Impacts on Society of Past Climate Changes. Global and regional climate changes will affect different societies and different segments within societies in a variety of ways. One means to determine the range of impacts is to undertake case studies on ways in which families, political institutions, and social sectors such as agriculture have been affected by changing or varying climates.

   How have patterns of settlement, economic development, social relations, and people's attitudes and images about the future been modified? Historical case studies of climatically vulnerable areas such as Iceland and the Great Plains of the United States may be particularly useful in understanding societal adaptations. Studies of societal responses to "surrogates" for climatic change, e.g., long-continued soil erosion or relatively rapid changes in sea level, could also be helpful.

   The basic resource for case studies should be a climate-society historical data bank, that is, a uniform, chronological set of data on climatic change over time and the impacts of these changes on societies. Initially, at least, the focus should be on the 13th century to the present and on Europe and North America, but as opportunity offers, the data bank should be expanded to include other times and other cultures.

3. Economic and Political Consequences of a Redistribution of World Water Resources. Using both historical climate data and computations from "general circulation" models of climate, the distinguished German climatologist, Herman Flohn, has recently estimated the changes in average surface temperature and precipitation that are likely to occur in different latitude belts if atmospheric carbon dioxide goes up 560-680 ppm. (The most probable value of 620 ppm is slightly less than twice the present amount of 335 ppm.) This CO_2 concentration could exist by about 2050 if present trends in fossil fuel consumption continue.

Flohn finds that, in the northern hemisphere, average rain and snow fall may increase by 20 percent between latitudes 10° and 20°N, while the average temperature in this latitude belt is expected to increase only slightly, about 2°C. On the other hand, at 40°N latitude, precipitation may decrease by 14 percent, while average surface temperature rises by 6°C. An even greater decline in average precipitation, about 20 percent, may occur at 10°S latitude, and 5 percent at 20°S, with increases in surface air temperature at these latitudes of 4 - 6°C. At latitudes higher than 25° in the southern hemisphere and 47° in the northern hemisphere, precipitation increases with rising CO_2, but average surface temperature also rises by 4° to 6°C. (See Table)

Probable changes in average annual surface temperature and precipitation at different latitudes with an increase of atmospheric CO_2 to 620 ±60 parts per million (somewhat less than twice present level)

Latitude	Aver. annual change in surface temp. °C	Change in precipitation
60° N	+ 7.5°	+ 18 %
50° N	6°	+ 4 %
40° N	+ 6°	- 14 %
30° N	+ 4.5°	0
20° N	+ 2.5°	+ 20 %
10° N	+ 1.5	+ 20 %
Equator	+ 3°	0 %
10° S	+ 4°	- 20 %
20° S	+ 4.5°	- 5 %
30° S	+ 4°	+ 5 %
40° S	+ 4°	+ 12 %
50° S	+ 3°	+ 12 %
60° S	+ 2.5°	+ 12 %

These changes will have profound effects on the world distribution of water resources. When precipitation exceeds evapotranspiration, the total surface runoff from a river system is simply the difference between precipitation and evapotranspiration (with a slight correction for underground seepage into the ocean). In the Colorado River basin of the United States at the present time, about

85 percent of the precipitation evaporates and only 15 percent is carried by the river. Because potential evapotranspiration depends mainly on surface temperatures, the percentage change in runoff due to climatic change is likely to be much greater, other things being equal, than the percentage change in precipitation. With a rise in average air temperature of several degrees centigrade, and a 10-15 percent fall in precipitation, the average flow of the Colorado could diminish by 50 percent or more. Yet even with large volumes of water storage, the present flow of the river is barely sufficient to meet present demands over a period of years.

With projected water uses for coal mining and transportation, geothermal power, oil shale production, and conversion of coal to synthetic gaseous or liquid fuels, these demands are likely to increase by about 10 percent.

If Flohn's projected changes in precipitation and rises in temperature due to increasing atmospheric CO_2 actually occur, radical changes in water allocations to different users or a large augmentation of Colorado River flows by interbasin transfer will be essential. Such changes in use or interbasin transfers would cause immense political and economic repercussions. Decisions made in the next few years can amplify or reduce these repercussions. A combination of economic, political, and technical analyses is urgently called for.

Very large changes in surface and underground water supply could also occur elsewhere in the world. In Northern Africa, the average flows of the Niger, Chari, Senegal, Volta, and Blue Nile rivers could increase by large fractions because of 10-20 percent more precipitation and only slightly higher surface temperatures. The flows of the Narmada and other South Indian rivers would also be expected to increase. On the other hand, the largest river in China, the Hwang Ho, the Amu Darya and Syr Darya in one of the prime agricultural belts of the Soviet Union, the Tigris Euphrates system in Turkey, Syria, and Iraq, the Zambezi in Rhodesia and Zambia, and the Sao Francisco in Brazil could greatly diminish in volume of flows. Somewhat smaller runoff and underground storage could also be expected in the Ganges of northern India, the Indus in Pakistan, the Danube in eastern Europe, the Yangtze in China, and the Rio Grande in the United States. All of these rivers form the basis of very extensive and highly productive irrigation agriculture, and the projected diminutions in their flow could have potentially disastrous consequences. On the other hand, the expected considerable increase in the flow of the Mekong and Brahmaputra rivers could
large areas of Thailand, Cambodia, Vietnam, India, and Bangladesh. The economic and social consequences could seriously worsen the situations of many Third World countries and part of the agricultural basis of the Soviet economy. Careful study should be made of

national and international actions, including investments in river basin development, that should be taken in the next few years to mitigate the effects that may be felt within the next several decades.

4. Risk-Perception, Information and Decision-Making. Societies respond only to conditions they perceive. Consequently, a pivotal aspect of the carbon dioxide question involves how people in different cultures perceive scientific and other information and make decisions based on their perceptions regarding adaptation or other responses. In the industrialized countries, many kinds of experts will provide information on climate changes, and policy-makers at all levels of society will decide how to act on that information. The problem of perception raises several provocative and researchable questions in social psychology.

   How reliable are the judgments of experts and decision-makers?

   Where do personal biases creep into expert judgment?

   What kinds of information does the public need in order to comprehend the knowns and unknowns?

   How will families perceive a problem and make decisions regarding their way of life?

   How do people combine multiple and conflicting risks and benefits of various options into a single decision?

   How can public opinion be accurately appraised as a guide to policy-making officials?

5. Possible Population Redistribution.

   Will the present southward drift of human populations in the United States and other countries such as Finland and Canada be modified by the much warmer temperatures expected at higher latitudes in these countries?

   If climatic conditions for agriculture deteriorate in Mexico and Central American countries, will population pressures for migration to the United States be intensified? Or, if agro-climatic conditions should improve, will economic development accelerate enough to slow migration?

II. CLIMATIC DATA BASES AND MONITORING

A research issue that cuts across all aspects of research on effects of CO2-induced climate change involves making different kinds of data accessible and useful. Although the work inventory of weather and climate data is extensive, these have not often been reported in a form most useful for predicting biological and societal responses to climate change or climate variations. Improved historical and current climate data bases would be desirable. The form of these data bases should be determined by collaboration among biologists, agronomists, resource managers, social scientists, climatologists, statisticians, and data processing specialists. Different forms may be required for agriculture and for social sciences. In tropical agriculture, crop/climate data systems need to be built and tested that will include information on regional climate and agro-resources such as soil, topography, and socio-economic conditions. Particularly for rain-fed agriculture, these data systems could be used in identifying zoning and mapping areas suitable for different crops and cropping patterns, based on climatic and agronomic constraints. More generally, agroclimate information combined with weather forecasts can be used at the farm level in selecting planting times and scheduling irrigation, fertilizer applications, and pest control measures. At the national level, it can be used for prediction of yields and prices.

Biological monitoring of forests and other natural ecosystems should be undertaken on a continuing basis to identify and evaluate effects of increased carbon dioxide and climatic change. Such monitoring should be carried out both on a reconaissance level and in greater detail at specially-chosen sites to study species successions and other relationships.

Mr. SCHEUER. That was very, very interesting, Dr. Revelle. We are grateful to you. I am sure we will have some questions for you at the end of the panel.

Now we will go on to Dr. Smagorinsky of the NOAA Laboratories in Princeton, N.J.

We will ask the remaining witnesses in this panel, and also the next panel, not to go over 15 minutes or we are never going to finish this morning.

As I mentioned, Dr. Smagorinsky, your full testimony and everybody's will be printed in the record in full. So if you chat with us for 12 or 15 minutes, we will move on and get to the questions.

STATEMENT OF JOSEPH SMAGORINSKY, DIRECTOR, GEOPHYSICAL FLUID DYNAMICS LABORATORY, NOAA, PRINCETON, N.J.

Mr. SMAGORINSKY. Thank you very much, Mr. Chairman.

After trying to second-guess what my colleagues on this panel were likely to touch upon, I thought it would be most useful if I were to concentrate on relevant studies being undertaken by the National Academy of Sciences, including some of the international facets of the question.

The Energy Security Act of 1980 calls upon the Office of Science and Technology Policy and the National Academy of Sciences to carry out a comprehensive 3-year study of the implications of anthropogenic increases in atmospheric carbon dioxide. The Academy is proposing that the study be organized and led by the Carbon Dioxide Assessment Committee of its Climate Board, under the guidance of the National Research Council's Carbon Dioxide Policy Group, and with assistance from other specialist units of the NRC.

Periodic letter reports will be transmitted to the OSTP, the DOE, and other agencies involved in the DOE carbon dioxide effects research and assessment program. The study will comprise two principal activities:

A continuing critical review of the government-wide carbon dioxide research and assessment program in the context of the national climate program. This review will endeavor to identify deficiencies and gaps in the program and is expected to yield timely and constructive recommendations to improve its scientific integrity, productivity, and utility;

Development of independent assessments of the carbon dioxide issue and certain of its specialized aspects, drawing principally, but not exclusively, on the results of the government program, but supplemented by the information, expertise, and judgment of the study groups.

More particularly, the Academy will:

Perform critical assessments of scientific knowledge on selected topics such as evaluating the accuracy of fossil-fuel consumption projections employed in estimating future carbon dioxide concentrations, understanding of the carbon cycle and how it affects atmospheric concentrations of carbon dioxide—which involves cultivation and deforestation practices, storage, and transport within the oceans and, of course, exchanges with the atmosphere—and evaluating research results on the response of climate to scenarios of atmospheric carbon dioxide increase;

Initiate and evaluate studies on the socioeconomic impacts of climatic changes such as on agricultural productivity, on health, on water resources, and on energy consumption—the sort of points covered by Professor Revelle.

Finally, the Academy will also review international activities such as those of the World Meteorological Organization, the United Nations Environment Program, the International Council of Scientific Unions, the European Economic Community, the Organization for Economic Cooperation and Development, the International Institute for Applied Systems Analysis, and other international organizations involved one way or another in carbon dioxide-related activities. It will advise on the desirable U.S. role in the development of a long-term, international program of research, monitoring, and impact assessment.

Since, in the scientific and impacts areas of inquiry, vigorous and continuing study is presently being conducted, both domestically as well as internationally, there is a need to delineate issues of consensus or uncertainty and to identify gaps that demand intensified attention.

The international dimension of the carbon dioxide question is not just important because it greatly enlarges the source of key data and the reservoir of expertise; fossil-fuel consumption, presumably the source of the problem, varies considerably from nation to nation.

On the other hand, the climatic consequences could be global, but with regional variations uncorrelated with the regional variation of major carbon dioxide sources. This then clearly would involve the socio-economics of all nations but in different and perhaps in conflicting ways, and it therefore becomes a potential international political issue. Since the United States is a major factor in all these aspects, we need to involve and to be involved with the world community of nations in pursuit of the carbon dioxide issue. Existing international government and nongovernmental bodies provide the vehicle for such an involvement.

Although this National Academy of Sciences program of which I have been speaking represents a recent attempt to deal with the complex of carbon dioxide questions comprehensively, the Academy has in the past several years already conducted a number of timely studies on various facets of the problem.

A case in point is the possible response of climate to increased atmospheric carbon dioxide. In the summer of 1979, the director of OSTP requested the president of the Academy of Sciences to conduct an up-to-date assessment of our understanding of the subject. A committee under the late Prof. Jule Charney of MIT produced a report which I would consider to be definitive for its time. In essence, it concluded that the result of a doubling of carbon dioxide concentration would be a global average warming of "near 3° C with a probable error rate of 1.5°C." This was based on numerical climate model simulations which were known to be deficient in a number of important ways: in particular, how the ocean's participation would delay the climatic response and alter its regional characteristics, and how and how much systematic changes in cloud distribution might react back to alter the sensitivity of the climate response.

Even in the intervening 2 years, many new research results have come forth, but not always elucidating the fundamental questions. One should note that the fact that differences of opinion exist is in itself significant. As a result the Academy, under its newly formed comprehensive study, commissioned a new evaluation and assessment of what has been learned in the interim. A report is now in preparation, but probably it will not be released until the end of the year after having passed through a thorough review process.

As chairman of this current Ad Hoc Carbon Dioxide/Climate Review Panel, I am not empowered at this time to disclose the as yet tentative conclusions. However, I thought this hearing would be interested in the scope of this particular study.

The input to our deliberations is an assumption on the projected loading rate of atmospheric carbon dioxide. This involves not only a prediction of the anthropogenic worldwide production rates, but also the role of the climate system, that is the atmosphere, oceans, cryosphere and biosphere, in absorbing, transforming, storing, transporting, and interchanging carbonates and other trace constituents which themselves interact—in short, the complex biogeochemical cycles. These processes are further complicated by the possibility that they in turn may be influenced by climatic change and variability.

To simplify the working assumptions, we have accepted as the best current estimate of net carbon dioxide loading rates those from a recent meeting of experts sponsored jointly by the World Meteorological Organization [WMO], the International Council of Scientific Unions [ICSU], and the United Nations Environmental Program [UNEP] [WMO, 1981]: ". . . the atmosphere carbon dioxide concentration in 2025 will be between 410 ppm and 490 ppm with a most likely value of 450 ppm."

However, because of the large number of existing studies addressing the effects of doubled concentrations, we are employing a doubling as a convenient benchmark. In any event, the range of effects between present concentrations and a doubling covers no significant thresholds, and our conclusions are not critically dependent on the detailed time evolution of carbon dioxide concentrations.

I would like to take the rest of the time, Mr. Chairman, to discuss this study.

The problem of understanding the climate's response to a given scenario of carbon dioxide change in the atmosphere is hardly distinguishable from the fundamental problem of understanding the natural variation and change of climate. For this reason, what is presently understood about the carbon dioxide question is largely the result of progressive developments in climate modeling over the past quarter-century. Climate models remain the most powerful means for dealing consistently and quantitatively with the complex system of highly interactive processes that determine climate.

Further progress in sharpening our insights and estimates on the carbon dioxide question, therefore, will continue to depend greatly on our ability to construct more faithful climate models, more faithful to the real geophysical medium.

Our emphasis is being directed to those modeling problems that we perceive now most specifically to impede our ability to make

sounder and more precise judgments on the likely response of the real climate to a given rate of carbon dioxide increase. For example, we are emphasizing radiatively connected processes because of the confusion in recent literature, and we specifically will discuss a few papers which suggest a lower climate sensitivity.

As was the case in the Charney report, the role of the oceans and the cryosphere, that is the sea's ice cover and the continental snow cover, still seem paramount in influencing the nature of the climatic response, particularly in its evolutionary qualities.

The possible interactive role that clouds may play in a shifting climate regime remains one of the major unresolved mysteries. The question is how the cloud field would vary in concert with other changes induced by carbon dioxide and thus alter the radiative transfer in the atmosphere. It is not yet even clear whether systematic cloud changes will provide a net amplification or an attenuation of the climate's sensitivity.

Also, in connection with the radiation fields are the interactive effects of other trace gases, nitrous oxide, methane, ozone and the freons, and also aerosols [continental dusts, marine salts, and volcanic sulfates]. Some new results indicate that, at least for the present, they cannot be ignored in addressing the carbon dioxide question.

Simplified climate models, which approximate only grossly the horizontal transport processes in the atmosphere, have become a popular tool for carbon dioxide analysis. We are endeavoring to delineate their strengths and weaknesses in contrast to the physically more comprehensive, but far more expensive and time-consuming, three-dimensional, time-dependent general circulation models of the atmosphere and ocean.

The confidence that one can place on the results of climate simulations is calibrated by a model's ability to replicate a variety of known physical states. Since laboratory-based, experimental sources of validation are virtually nonexistent, we must depend upon empirical determinations gleaned from the geophysical medium itself. The observed contemporary climate is one such obvious source, especially its geographical, seasonal, and interannual structure. Furthermore, past climates provide the only records of large excursions in climatic regimes and are a key testbed for developing and testing climate theory.

It is becoming increasingly clear that the major climatic changes on the scale of glacial fluctuations are at least in part produced by the temporal and latitudinal changes of solar radiation brought about by slight changes in the earth's orbital parameters. This finding promises a major advance in our knowledge of the sensitivity of climate to small but well-known changes in external forcing. With both external forcing and climatic changes identified, there is an opportunity to identify and to quantify the role of internal feedbacks. In particular, studies of past climates may be especially germane to the carbon dioxide question because there is evidence that atmospheric carbon dioxide itself may have undergone large variations in the past. Very often only limited properties of the climate system of the past can be ascertained.

For example, in the case of the last Ice Age, 18,000 years ago, it is primarily the polar ice perimeter, the sea surface temperature,

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and continental vegetation regimes that can be reconstructed, to a limited extent seasonally, but with limitations both temporarily and geographically. Because the state of the climate system is incompletely known, even at present, every attempt must be made to determine the state as completely and with as little ambiguity as possible.

We are documenting the methods of validation of climate models which can presently simulate climate and its variation. Special emphasis is being given to the oceans because of their central and only partially understood role.

One of the validation objectives specific to the carbon dioxide question is the early detection of actual carbon dioxide-induced climate changes predicted by climate models. Here one wishes to identify a small but systematic signal that may be obscured by the background of natural variability. This variability is large. But if this variability were understood, it could be internally generated by the climate model, which then could be used not only to determine the optimum climatic indices to monitor, but also when, where, and how to monitor. However, should the model not incorporate an important climatic process, such as the effects of ubiquitous trace gases or an ability to account for the effects of an extraordinary event such as volcanic eruption, a monitoring strategy based on model simulations could well be misleading.

The end product that is needed to assess the likely impacts of climate change on human activities is a comprehensive picture, or to use a cliche, a scenario, of the time-space structure and the amount of that change. Noting that local climate has a much larger temporal variability than the global mean climate, then the relevant climate indices will depend on the particular activity under consideration.

For example, temperature, precipitation, soil moisture, and solar radiation reaching the ground will be germane to an assessment of the impacts of climatic change on agriculture. In our report we will address the question of scenario development, with some indication of our present abilities and measures of uncertainty.

Finally, despite the admitted existence of numerous uncertainties, the consensus on the nature and magnitude of the problem has remained remarkably constant throughout this long worldwide process of study and deliberation, in some instances going back to a century ago. Burning fossil fuels releases to the atmosphere carbon that was extracted by ancient plants many millions of years ago. The most recent projections of future energy consumption suggest a slackening in the growth in energy consumption, but nevertheless, even the most conservative estimates imply major carbon dioxide injections.

The details of the natural carbon cycle and the future disposition of injected carbon dioxide are still unclear, but it seems certain that much manmade carbon dioxide will remain in the atmosphere. Although questions have been raised about the magnitude of climatic effects, none deny that changes in atmospheric carbon dioxide concentrations have the potential to influence the heat balance of the earth and the atmosphere.

Finally, although possibly beneficial effects on biological photosynthetic productivity have been recognized, none deny that an

altered climate would to some extent influence how humanity secures its continuing welfare.

As I indicated earlier, this report will address the uncertainties in but one element of this consensus: the effects of changed concentrations of airborne carbon dioxide on global climate. Other questions will be similarly undertaken in the course of a comprehensive National Research Council study of the entire issue which is to be conducted over the next several years.

Thank you, Mr. Chairman.

Mr. SCHEUER. Thank you very much.

I already have enough questions for Professor Revelle and for you, Mr. Smagorinsky, to take us through the afternoon. I announce that with regret to my colleagues. Your testimony was very stimulating.

Next we will hear from Dr. Schneider.

STATEMENT OF STEPHEN SCHNEIDER, DEPUTY DIRECTOR, CLIMATE PROJECT, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, COLO.

Mr. SCHNEIDER. OK, Mr. Chairman, I will take your admonition to speak extemporaneously seriously, and I know I will pay for it when I get the transcript and I try to make English out of what I have said.

What I want to talk about, since Dr. Smagorinsky and Dr. Revelle have so well covered many aspects of the problem, is the question primarily of so what, if carbon dioxide increases? So what if the climate changes? This necessarily is an economic, social, and political question as well as a physical and a biological one.

Since we need economic input and since the economist Lester Lave will be able to speak after me, it is only fair that I can tell an economist joke to get started, since he will be able to tell a climatologist joke when I am finished.

It is one I belive that Oscar Wilde was first credited for, an old cliche, when he was reported to have said that an economist is one that knows the price of everything and the value of nothing. That is what we really have to deal with: price and value.

We have to ask how the costs of mitigation of carbon dioxide or its effects stack up against the costs, in some pricing way, of doing nothing. In other words, will the consequences have costs which we have to balance against the costs of doing something about it?

So there is a pricing part. Also there is a value part, because we have to value the present versus the future, because often the costs that we incur to do something about it now are paid in this year's dollars whereas the costs from anything that may go wrong might be incurred decades in the future.

Mr. SCHEUER. Dr. Smagorinsky remarked that the range of effects between present concentrations and a doubling covers no significant thresholds and our conclusions are not completely dependent on the timing of carbon dioxide concentrations. If there doesn't seem to be a significant effect to a doubling, where is the critical point? Where do we run into a real problem? How far away? What will the problem be? What are the mitigating or controlling policies that we should be formulating now, if any?

Mr. SCHNEIDER. Yes. Well, in partial answer, I won't use up all of my 15 minutes on it, that question is a creeping or incremental kind of issue. It is one which our political systems have had a great deal of difficulty dealing with. A good analogy is air pollution or soil erosion where another little increment of it is certainly not going to have people keeling over in the streets.

This is what one of my ecological colleagues refers to as "the corpse theory of death." People infer that if another increment of pollution can't obviously do anything visibly bad it isn't dangerous; yet the cancer rates in 50 or 60 years may show it. So we have the kind of situation where there is a slow or incremental creeping cumulative effect.

If you lose a little soil, you lose a little crop yield, but not enough to make a dramatic difference. It is only when the soil horizon gets very low that it becomes so obvious that it is clear that something should be done. What we have to learn to do is recognize incremental problems which in each individual year seem to be no change, yet if you step back and take a long look you can see a big change. That is really what carbon dioxide is.

In a way it is a prototype of many other socio-technical problems that we have. Perhaps the best way to summarize the perspective of the so-what question is to take a look at it with a view to all the other aspects of the problem. I have done that in my prepared statement on page 6 in figure 1, in what is called the carbon dioxide pyramid, and this is an inverted pyramid, it stands upside down.

Any physicists in the room realize an inverted pyramid is unstable. Somewhere down in the corner there are a couple of scientists of various forms trying to hold this up. That is what our research is about, to try to fill in all of the blocks in this pyramid. Right at the bottom is a box, or rather triangle, labeled "behavioral assumptions," meaning the carbon dioxide-producing activities of man.

The irony is that the very base of this pyramid is not so much physical and biological science, but social science. The questions are: What will the population be in the future? What will the per capita consumption of energy be? These are very much economic questions, and also questions of value; another question that lies at the base of these behavioral assumptions is: Will we have coal trade? Will the United States, Russia, and China be involved in a COPEC, a coal producing and exporting cartel, and if that is going to happen and coal could end up in the hands of various and sundry people in the world, will they buy it?

If the most populous nations are going to buy it, they are going to have to have the foreign exchange to do that. That means they will have to get their food situation straightened out first. So we also have to make assumptions as to how they, many nations in the world, will be fixed with regard to food problems.

If a breakthrough comes along so they don't have to buy food, then they can use money to buy coal. These are the questions one has to guess in advance when trying to figure out the rate at which carbon dioxide will increase. It lends itself very well to scenario analysis. It is interesting that right at the bottom of the whole CO_2 question are projections of human or behavioral assumptions.

The next question is the carbon cycle response. Supposing we have either a scenario or a perfect model devoid of catastrophes of a social nature which tells us how humans will behave and how much fossil fuel we will use and what alternative energy systems will come along; then we have to figure out how nature disposes of that carbon.

There is a factor of perhaps two uncertainties in that, maybe less; it depends on how much you believe that the biosphere and the oceans will interact.

The next question, which I personally spend a lot of time on, is the question of the global climatic response to CO_2 increase. The number you often hear is if carbon dioxide doubles the surface temperature will increase something like 2°, 1 to 4 or various ranges; so what if it is 1 to 4, what does that mean? What is 1°?

In order to have any way to valuate what that means for us in any economic or social sense, you have to have some information about a regional climatic response associated with that 1 degree. That means we need to know the kinds of information that Roger Revelle referred to, such as what will happen in the midlatitudes. What happens in the graineries, or to the water supplies? We need such information if we are ever going to do any juggling as to cost and benefit analysis.

Mr. GORE. May I interrupt you there?

I want to focus that particular set of questions in a more narrow way for the policymakers on this committee. What happens to the United States? I want to address the question within that framework which may be one of several contingencies.

Mr. SCHNEIDER. Fine, I agree completely. Unfortunately, the difficulty is we will never have a perfect consensus on CO_2 climate impacts. There will always be a stroller in every community who doesn't believe something that most others do. Consensus has been developing fairly nicely on the global climatic response to CO_2, but we are far away from that consensus on the regional question because it is tougher and more expensive to try to answer it since one has to use more detailed models which become less certain as one gets more fine detail. So what you need most, we have the greatest difficulty in providing with great reliability. Again it is leading to scenario analysis.

Then the next question as we move up this pyramidal ladder is, all right, what if we have a scenario of regional impacts? I do not know if any of you have ever driven across the sand hills of Nebraska, a beautiful region between Alliance and Broken Bow. I did that two summers ago. It is a nice grazing land, remarkably productive for what was merely 5,000 years ago drifting dunes; 5,000 years ago the planet was perhaps 1° or 2° C warmer than today, possibly not because of carbon dioxide, though there is some possibility of it. Yet that region was radically different in its climate than it is today.

There was a so-called prairie peninsula effect in this period about 3,000 to 8,000 years ago when what is now our Corn Belt was quite a bit drier. The evidence of this is that the fraction of pollen in the soil sediments shows a larger component of herbs than it does today east of the Missouri River.

So, that again would not be helpful for our present agriculture; that was a time when the global temperature was 1° or 2° different. Again we are getting to the point that we know this 1 degree is nothing more than a measure of a change in global climate. To translate that back to regional changes, we have to have the right sort of information. So we look at paleo-climates and computer models and try to combine these things to give us a scenario of what regional effects could be.

If we had a scenario, with the change in the precipitation or soil moisture or some other element, we then could use the models and theories we now have, and the experience of the past to figure out what would it mean to crop yields, to water supplies, and so forth. But in order to do that, we also have to guess, if we are talking 20 years or 50 years in the future, what kind of new genetic crop strains will be available, as Roger Revelle mentioned, and will they have in fact different responses to the climate change we project than our present one.

So part of our scenario has to be projecting what the future resource base will be, what its availability will be. Also, we have to project what kind of soil we will have left in these regions given the way we now perform virtually nonrenewable agriculture by mining the soil. This is another major question. So all of these issues interact when you try to guess what will happen in the future.

The sea level question of course is in as a future projection as well. I include in any scenario the health question, something we very rarely deal with—we keep talking about it in our meetings and end up never directed at it specifically. Roger Revelle mentioned health effects with regard to stress on the elderly, if, for example, an extreme heat wave were 2° hotter. Because we are very nonlinear beings, that extra 2° can be much more serious if it is 100° to 102° than from 98° to 100°.

In another sense, health may be even more important; that is, there are a number of vectors of disease, such as insects, controlled by the winter freeze line. If one expands that back, will there be marginal changes in which such winter kill of disease vectors will no longer be limited to the present regions but move out marginally? These sorts of issues from CO_2 increases are just barely beginning to be addressed and could have in fact very large human and animal health implications which we really have almost nothing to say on more than that one sentence.

When we get beyond those impacts mentioned so far, and they may not all be bad as Roger Revelle said, you are also certainly going to increase photosynthesis from CO_2 increase, thus increasing the growth rate of plants. But, can we make sure we take advantage of it by having faster growth in the part of the plant we want; but, you are also going to be increasing the growth rate of weeds and plants which are a host to insect pests and thus we have a very difficult problem of trying to decide which effect of enhanced photosynthesis wins and which loses.

On top of this is the question of what are the social, economic, and political aspects of these impacts. Here is where the cost-benefit analysis comes in, our economists and their methods, what-

ever we want to call them—we need them—to try to figure out what the juggling or balancing act is.

We also have the political question of, do you add up all the impacts for the United States as a whole and get some price, positive, negative? Or is it important who wins and who loses? How does one weigh equity?

Supposing one part of the Nation would benefit greatly and another part would be hurt but there would be no net national change, does that mean there would be no problem? I doubt it, because there is a political question coming from that equity stress. Trying to come up with definitive answers from what is now known is absurd, because all you can do is try to build a scenario and find out where the critical points are.

Ultimately, at the top of the CO_2 pyramid is the question you are most interested in: What are the policy responses? They have general categories such as adaptation or prevention; you can even have climate control if you wish. Policy response sits at the top of this large pyramid of cascading uncertainties, and it is this bundle of cascaded uncertainties which has led so many people to say this is an intractable problem, there isn't very much we can do about it.

I would challenge that in a little bit in my remaining 3 or 4 minutes by saying there is a hierarchy of responses that you can consider. The first one, and it is a policy, is to do nothing and that is not one that is widely advocated—except by some special interests.

Then the second one, which is a little more radical but not very, is the one we have been doing, and that is to study the problem. After all, studying is a policy decision, we have decided to try to invest in research to try to get more information so any policy we take in the future can be made on a firmer basis. And obviously I support that, but then again I have to confess having somewhat of a special interest in research. Fortunately there have been a number of other bodies who don't who have agreed with that. It is pretty hard to argue that more information would make rational policymaking any worse.

There is a sidelight to that question and that is that some people have said that CO_2 is far enough away so that studying it is where we should draw the line simply because it is at least 10 or 15 years before a CO_2 effect becomes clearly detectable, and it could even be 20 or 30 years. So we could comfortably wait this 20- or 30-year period during which we study before we have to take any actions more strong than that.

It is certainly true that the problem is decades away before there is a large or detectable signal. This isn't the place to discuss it, but you can argue it has been detected already because if you try to fit the record of the last 100 years of Northern Hemisphere temperature to a model—predicted record, you improve the fit of the model by assuming that the carbon dioxide has the response near to that predicted by models. But the model fit to the data is not yet statistically significant.

But if we go back and say we even have 20 or 30 years before the CO_2 effect is clearly detected, we are still going to face a risk. That is, we will have to adapt to a larger dose of carbon dioxide and its

consequences, good or bad, if we wait until we are sure, than if we act now and reduce the carbon dioxide burden.

The next most active policy step, which is the one I personally advocate, is to try to what I call "build resilience" in my prepared testimony—namely, do whatever you can now to increase the number of options you will have available in the future so as the information comes in and the problem becomes clearly a problem or not, you have the flexibility to move.

Mr. SCHEUER. Are you going to describe what those options are?

Mr. SCHNEIDER. Yes. Well, very briefly, one of them has already been mentioned by Roger Revelle, that is to work vigorously on the development of crop strains which can be more widely adapted to a variety of environments. That way you have an inventory from which you can choose, as you see the climate evolving. That is something we should do anyway, regardless of carbon dioxide, which only reinforces that need.

A second one to me is to try to maintain the soil horizons and minimize soil erosion because you are going to need every drop of productivity you can get in the future, considering population growth and other factors. If we are going to have the potential for reduced yields from CO_2 effects, we don't want to add to it by having lost some of the soil too. Again, this is not only a carbon dioxide issue, the soil erosion issue exists without it.

Another way you can build resilience is to develop vigorously alternative energy systems stressing renewable and efficient technologies. They do include some of the kinds mentioned earlier, although I might prefer a different mix. To me the basic principle is: You don't get hooked on one source.

Again, we don't need a carbon dioxide problem to restate that sort of simple obvious piece of wisdom, but carbon dioxide lends more impact to the need for doing that. It also raises other questions such as: Would that happen if we only practice market economics? If one takes a strategic view of energy and says our future options require some degree of nonmarket intervention to develop alternatives, this is a way you build resilience and deal with the carbon dioxide problem because you have the standby capacity to shift to other developed supply options if you needed to. Again, it would involve some up front costs, like buying insurance has premiums.

Finally, the most radical policy options you can take to respond to CO_2 would be what I have called, in fact Margaret Mead first called it, the "Law of the Air"; namely, each nation agrees by some negotiation to what its polluting rights are with regard to carbon dioxide. I think this option is about as realistic as, well, getting everybody to agree on everything. Although one can argue that is ultimately where we should be going, it is certainly not reasonable at the present as, in my view, the uncertainties are too large.

So in conclusion then, the basic message from taking a look at the CO_2 issue is that although the problem may appear far away, the time it takes for one to change energy systems, which can be decades or more, and the time it takes to build resilience and give you the options which give you flexibility really make it a problem now in the sense that you want that long lead time to react. If you delay the more active policy responses, it just means you will have

to deal with a larger input of carbon dioxide later on. This has to be recognized.

I have about six or seven various national and international reports quoted in my prepared statement, all of which said basically the same thing: That they viewed the overall carbon dioxide problem—I also quoted from Congressman Brown at the beginning and end of the testimony and I will not repeat his words, he is here—as both an inherently international problem and an interdisciplinary problem which has to be viewed as a physical, biological, and social problem.

The "so what" has been emphasized as of comparable importance to other problems by every group, including physical science groups which have studied it. I will cite a quote from a meeting held in Villach, Austria, in November 1980 which was a meeting of experts jointly held by the World Meteorologic Organization, International Council of Scientific Unions, and United Nations Environment Program, which are connected with the world impacts program, a program just getting going now. They called for a major international interdisciplinary research effort necessary to develop a set of impact scenarios based on extended sets of data not now available so as to deal successfully with uncertainty and prepare a management plan of action adequate to cope with likely impacts.

There is more of that statement in the prepared testimony. I won't take the time to read the rest since it is there. But basically, what it all suggests is the way one approaches an intractable inverted pyramid is by assuming climate scenarios and making sure these scenarios, not of just climate, but of social behavioral economic assumptions, are at least internally consistent. The hope is we will thus be able to find out what smaller changes now can have larger positive impacts on the future, and where we should most efficiently apply resources.

Ironically, this conclusion to press scenario analysis also was the one that came out from the Department of Energy's impact assessment part of its study. The Department has had a carbon dioxide assessment program for a long time, but impact assessment is a more recent focus.

One phase of it was for the study of impacts, both environmental and social. All of us at this table have been involved in that effort. The process began with a meeting in Annapolis back in 1979 or 1980, from which I quoted Congressman Brown's remarks in my prepared statement. There were over 100 people there. It really was a cacophony, one came out of it with a headache, there were so many different disciplines trying to figure out and make sense of the CO_2 problem.

Phase 2 of the AAAS/DOE effort was to boil that Annapolis report down through a steering committee, of which a number of us were cochairmen. In all, there were five panels, one on physical effects on the ocean, two on the effects on the biosphere, managed and unmanaged, then social and institutional effects which I was involved with, and the economic and political one which Lester Lave was involved with.

We tried to distill this vast array of information down and come up with a series of tractable research proposals. We boiled this down to the five panel reports, which ultimately led to the final

project suggestion which was that the highest priority item was to do an integrated impact assessment based on these integrated scenarios.

I am very glad DOE has representatives here to talk to that recommendation. My final remark is that without that kind of analysis, I feel any CO_2 program is not really looking at the question.

Mr. SCHEUER. DOE will be in the next panel. You can be sure we will direct that question to them.

We will now hear from Dr. Lave, who has helped us on past occasions in addressing other problems.

[The prepared statement of Mr. Schneider follows:]

Testimony of

Stephen H. Schneider

National Center for Atmospheric Research*

P.O. Box 3000

Boulder, Colorado 80307

on

Carbon Dioxide and Climate:

Research on Potential Environmental and Societal Impacts

before

Subcommittee on Natural Resources, Agricultural Research and Environment

of the

House Committee on Science and Technology

Friday, July 31, 1981

9:30 a.m.

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"The carbon dioxide problem presents the scientific and political arenas with enormous challenges as well as significant opportunities. It is a problem of historic proportions, truly global in scope, and with profound implications for the full spectrum of human activities...To address the problem requires mounting an effort in pre-crisis management. As participants in this workshop, you are involved in the evolution of such an effort; an exercise in foresight of unprecedented scope. The great significance of this pre-crisis mode of activity becomes evident when you consider that we live in a world with post-crisis response, which has been the dominant mode of problem solving for far too long." (1).

These words were written by Congressman George E. Brown, Jr., and presented before the American Association for the Advancement of Science/ Department of Energy, "Workshop on Environment and Societal Consequences of Possible CO_2-Induced Climate Change," which brought together more than 100 scientists from many disciplines to look at the potential impacts of carbon dioxide. The results of this workshop, held in Annapolis in April, 1979, led to a series of research recommendations designed to put on a firmer scientific basis the need for any policy actions to deal with an impending CO_2 problem. But why worry at all about the CO_2 issue? A brief review may be helpful to put perspective on the need for evaluating potential impacts and public policy responses.

The Corn Belt and Great Plains of the United States comprises the principal food producing and exporting region in the world. We owe much of this to favorable climatic resources of the region. For a number of years, particularly in the mid-1930s and the mid-1950s, and to a lesser extent in

the past few years, climatic conditions have not always been as favorable; economic and social hardship followed in the wake of these episodes of bad weather. But some 5000 to 8000 years ago, when mean global temperatures were perhaps 1-2°C warmer than today, dunes of drifting dust covered major portions of the high plains and prairie-like conditions now found generally west of the Missouri River invaded deep into the present Corn Belt, stretching all the way into Indiana, in what some archaeologists have called the "prairie peninsula." While CO_2-induced climate change is certainly not the only--nor even necessarily a principal--cause of this climatic event, the important message for our purposes is that seemingly small changes in global temperature can be reflected by large, regional changes in temperature and precipitation patterns. While such alterations are not necessarily bad, depending upon the nature of economic activities in each region when the climate changes, the important point is that we will have to learn to adapt--or migrate--should such climatic shifts occur in the future.

While the events 5-8,000 years ago were almost certainly a result of natural causes, human activities which alter the earth surface and the atmospheric composition could well cause significant global temperature changes over the next few decades. The human activity now believed by most atmospheric scientists to have the greatest likelihood of modifying the <u>global</u> climate is the release of carbon dioxide to the atmosphere from the burning of fossil fuels (coal, oil and gas) and, probably to a lesser extent, from the destruction and burning of vast tracts of forest land, particularly in the tropics. This concern has recently been endorsed by a

study of the U.S. National Academy of Sciences (2) and by an international meeting of experts held under the sponsorship of the United National Environment Program, International Council of Scientific Unions, and the World Meteorological Organization (3).

Recognition of the possible impacts of increasing carbon dioxide on the climate is not new, but was first recognized in the late nineteenth century. It is based on the knowledge that CO_2 more easily allows sunlight to reach the earth's surface than it permits outgoing so-called terrestrial infrared radiation from escaping to space. This had led to the common appellation "the greenhouse effect." Fossil fuels, ironically, are really storehouses of ancient carbon dioxide and solar energy. That is, many tens and hundreds of millions of years ago, carbon dioxide was removed from the earth's atmosphere through photosynthesis in green plants, and with the energy of the sun, the CO_2 was converted to plant carbohydrates--the same process which occurs today. When these plants fell to the bottom of swamps or shallow seas where oxygen was limited, they did not decompose immediately; they were able to be preserved in an organic form. Sediments built over them; immense pressures and time eventually converted these organic remains to the fossil fuels upon which global economies depend today.

By burning a lump of coal or a gallon of gasoline we are merely returning to the environment the CO_2 and solar energy taken out of it tens to hundreds of millions of years ago. However, technology and human numbers are now such that the rate at which we are returning these to the environment vastly exceeds the rate at which they were originally with-

drawn. Similarly, it can take decades to build up the carbohydrates in a treetrunk, but only minutes to burn them down and liberate the CO_2 into the atmosphere. Thus, the CO_2 problem is one of the rate at which we inject CO_2 into the air relative to its uptake by natural sinks. For the last twenty to twenty-five years, during which reliable measurements have been available, there has been about an 8% increase in CO_2 in the air. This represents about half of that which has been injected into the atmosphere from the burning of fossil fuels over this period, suggesting that some CO_2 sinks are active.

In order to help put perspective on the CO_2 problem we can list each of its many subcomponents on an inverted pyramid, as on Fig. 1 (4).

Behavioral Assumptions. At the very base of the CO_2 pyramid of problems is neither physics nor chemistry, but rather social science. That is, the amount of carbon dioxide injected into the atmosphere over the next several decades is not known--nor is it precisely knowable. It depends upon underlying behavioral assumptions as to what will be the CO_2-producing activities of man. These depend upon projections of (a) human population, (b) the per capita consumption of fossil fuels by that population, (c) the deforestation activities of man, and (d) even any engineering countermeasures to remove CO_2 from the environment. These, in turn, depend on issues such as the likelihood that alternative energy systems will be available, their price, or their social acceptability. It also relates to food. For example, before a significant fraction of the world's coal can be used by most Third World countries, it will have to be shipped from the principal coal-endowed nations: the USSR, the U.S., and China. In order

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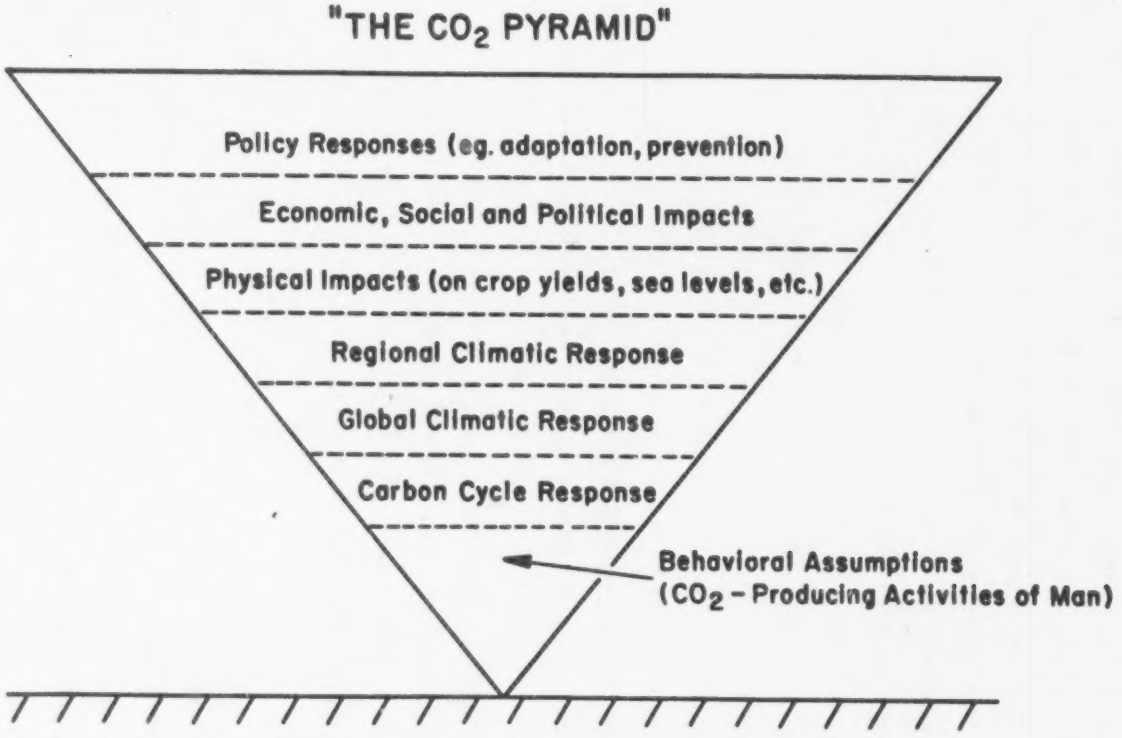
"THE CO_2 PYRAMID"
Policy Responses (eg. adaptation, prevention)
Economic, Social and Political Impacts
Physical Impacts (on crop yields, sea levels, etc.)
Regional Climatic Response
Global Climatic Response
Carbon Cycle Response
Behavioral Assumptions
(CO_2 - Producing Activities of Man)

Figure 1 (From Stephen H. Schneider, 1981)

for most countries to purchase coal after oil production tapers down around the turn of the century, it will be necessary to have sufficient foreign exchange to buy it. Whether such financial resources will be available depends upon the food situations of these countries, particularly the most populous, which in turn depends upon technological, economic, and political assumptions as to how food demands will be met.

Carbon cycle. Assuming we can, at least to an average of 50%, estimate how much CO_2 might be produced in the next few generations, we must then analyze how the global carbon cycle will accept or dispose of the CO_2. This involves questions such as the uptake by the oceans, the uptake by photosynthesizing green plants, and the deposition of carbonate chemicals in marine or other sediments. At present there is considerable controversy over the relative roles of the oceans and biosphere in accepting--and producing--CO_2. Furthermore, if CO_2 increases, it will change the rates at which plants grow, and perhaps change the climate in such a way as to alter both biological and oceanic sources and sinks of CO_2. Nevertheless, models of the carbon cycle do exist and are able to reproduce with some success carbon dioxide fluctuations of the past decade or so. If these models are combined with the behavioral assumptions behind CO_2-producing activities, then projections--better to call them scenarios--of future CO_2 amounts can be made. These typically suggest a ten or so percent increase over present amounts in the CO_2 concentration around the end of the century, and the doubling of carbon dioxide before the end of the next century.

Global Climate Response. If such CO_2 increase scenarios are derived, they can be fed into models which predict the global climatic response.

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Such CO_2 increases as projected are relatively unprecedented--at least if they occurred we have insufficient measurements to verify either how much CO_2 was there or what climate changes occurred. As, in this sense, they are unprecedented, we have little choice but to build models of the earth's climate in order to simulate the sensitivity of the present climate to projected CO_2 increases. Although there is considerable uncertainty in the reliability of such models, since there is no direct verification possible, nevertheless indirect tests of the models can and have been done. Indeed, assessments by national and international groups of scientists almost always produce the same conclusions: that a fixed doubling of carbon dioxide would increase global surface temperatures by something between 1.5 and 4°C. Unfortunately, CO_2 in the real world is not a fixed doubling, but a smooth increase over time. The effects of the oceans in altering the actual course of the climate over time relative to the effects predicted with model calculations in which CO_2 is doubled and held fixed is now a subject of debate in the scientific community. It is important to predict the actual time-evolution of CO_2-induced climatic change because it affects what is needed for human societies to determine how to react to the problem: namely, scenarios of regional climatic changes.

Regional Climatic Response. Although we may now have achieved some consensus on the global climatic effects of increasing carbon dioxide, what is important for economic and social impact studies is the regional response. Unfortunately, to predict regional responses requires climatic models of greater complexity--and expense--than needed to make global pre-

dictions. Nevertheless, those few models which have been applied to this problem tend to suggest certain coherent features. These include wetter subtropical and monsoonal rainbelts, longer growing seasons in the high latitudes, wetter springtimes in high and midlatitudes, and--most problematically for our future agriculture--drier midsummer conditions in mid- and some higher latitudes. Considerable uncertainty still remains.

Physical CO_2 Impacts. Given a scenario of regional climatic change, we can next estimate its physical impacts on the environment and society. Most important, of course, would be its effects on crop yields. Next is the potential for altering the range of some pests which could impact on human or animal health. Also of interest would be how yet undeveloped environments, such as tropical forests, might be altered. In addition, changes in patterns of heating and air conditioning demand would occur, as might the potential for using some renewable, environmentally dependent energy sources. Perhaps the most dramatic, even if far off, potential event, would be the breakup of part of the West Antarctic Ice Sheet, possibly resulting in a five- or so meter sea level rise. One estimate suggests that several percent of the U.S. land area could be lost if such an event occurred.

Economic, Social and Political Impacts. Before one can seriously suggest policy responses to the advent or prospect of CO_2 increases, all of which might entail costs, one first needs to examine potential costs--and benefits--of CO_2-induced environmental or societal impacts so that these can be weighed against the costs of mitigating strategies. This is not a simple question of aggregating total dollars lost or gained, but also

involves the important equity question of who wins and who loses, and how the losers can be compensated and the winners taxed. Moreover, even the perception that the economic activities one one nation created climatic changes which might be interpreted as detrimental to another, has the potential for being divisive to international relations. Nevertheless, given scenarios of behavioral assumptions, carbon cycle response, global climatic response, regional climatic response, physical impacts, and economic infrastructure in the future, we can estimate, particularly for agriculture, some potential economic, social and political impacts. For example, in the aforementioned case of coastal flooding, a five- to eight-meter sea level rise would cause something on the order of a trillion dollars in lost U.S. property alone. However, if such an event occurred one hundred and fifty years in the future, it would certainly not be viewed by most present policy makers as "worth" a trillion dollars, but rather would have to be discounted significantly, depending on one's economic--and ethical--view of discounting the future.

Policy Response. Finally, at the top of our inverted pyramid on Fig. 1 sits a category, "policy responses," which include the possibility to adapt, prevent, or even attempt to ameliorate the buildup of CO_2 or its consequences. Schneider and Chen suggested four possible policy responses (5):

(1) Do nothing.

(2) Study and monitor.

(3) Build resilience (that is, increase available options to deal with the advent or prospect of CO_2 buildup).

(4) Law of the air (that is, set up national emission quotas for CO_2 based on international negotiations).

Obviously, very few, save a few special interest groups, suggest the first alternative and very few, save a few passionate believers, feel it is appropriate or politically feasible to negotiate a "law of the air" in the near future. Although I recognize my own special interest in recommending research, it is easy to justify the need to elaborate on the physical, biological and social components of the CO_2 problem in order to place any policy making--present or future--on a firmer scientific basis. However, only studying cannot be accomplished without some risk. That is, if we wait ten or twenty years before proceeding with more vigorous actions, then we will have to adapt to a larger amount of CO_2 and its consequences than if actions were taken now to either increase our options to deal with CO_2 issues in the future, or to eliminate CO_2 emissions.

My personal view is that the "build resilience" option is not premature, for many of the actions needed to minimize the potential risks of CO_2 buildup are also valuable in their own right. For example, development of genetic crop strains more able to deal with environmental variations would help minimize any adverse CO_2 impact on agriculture, and certainly would be valuable to deal with other causes of climatic fluctuations. To develop a host of alternative energy systems so that quick shifts may be possible should supply interruptions for political, economic or safety reasons occur in the future is another example of a way to increase options to deal with CO_2 or related energy problems.

One thing that is clear from this brief perspective on the CO_2 issue: it is international and interdisciplinary. This point has been emphasized by all of the more than a dozen national and international groups which have seriously looked at the CO_2 question. Moreover, it cannot be addressed from the point of view of physical science alone, but also must equally consider biological and social science components. This was explicitly recognized, for example, in the National Climate Program Act. Section II of the Act reads,

> The Congress finds and declares the following: ...an ability to anticipate natural and man-induced changes in climate would contribute to the soundness of policy decisions in the public and private sectors.

In Section V, under "Program Elements," the Act declares,

> The program shall (2) include, but not be limited to, the following elements: ...basic and applied research to improve the understanding of climate processes, natural and man-induced, and the social, economic, and political implications of climate change...(6) measures for increasing international cooperation in climate research, monitoring, analysis and data dissemination."

It is important to note that this Act, and its subsequent several renewals--including the Department of Energy's acceptance of "lead agency" status for all CO_2 climate research--has been passed by both houses of Congress with virtually no dissent. This recognition on the part of Congress that CO_2 and other climate research problems are not partisan, but rather national issues is reassuring. I sincerely hope this bipartisan action continues.

A number of other assessment groups have discussed the CO_2 and climate impacts issues. For example, the introduction to the Report to the Inter-

national Workshop on Climate Issues states that a proposed World Climate Program will have three components, one of which is impact studies. "The impacts component will attempt to understand and describe the impacts on society of climatic variability and change. There is an important need to understand how climatic factors directly affect the various economic sectors and how these amplify and disperse through secondary and tertiary effects on the whole economic and social system. Such understanding is essential for directing the research and applications of the World Climate Program at the most urgent problems and for enabling planners to make appropriate decisions relating to climate." (7) Indeed, in the report of the February 1979 World Climate Conference, the delegates proposed a World Climate Program with a major impacts thrust, stating that "the overall purposes of the program are thus to provide the means to foresee possible future changes of climate and to aid nations in the application of climatic data and knowledge through the planning and management of all aspects of man's activities. This will require an inter-disciplinary effort of unprecedented scope at the national and international levels." (8)

A Congressional Research Service report prepared for the House Committee on Science and Technology in 1976 stated in its perspective that "the far-reaching consequences of a major unanticipated change of climate in the modern world indicate the need not only for making climate research efforts more structured and focused, but also for establishing an adequate, ongoing climate monitoring program to gain the information needed to clarify the mechanisms, causes, socio-economic and international implications of climate change." (9) This study served as one of the background

documents which led to Congress' passage of the National Climate Program Act.

About the same time, a National Research Council report on energy and climate appeared, and in its foreword, the authors wrote: "To reduce uncertainties and to assess the seriousness of the matter, a well-coordinated program of research that is profoundly interdisciplinary in character and strongly international in scope, will be required. This research, much of which is outlined in the present report, should extend beyond scientific and technical considerations to include the complex factors and the institutional innovations that will enable the nations of the world to act with wisdom and in concert before irreversible changes in climate are initiated. If the preliminary estimates of climate change in the latter part of the 22nd Century are validated, a reassessment of global energy policy must be started promptly because, long before that destined date, there will have been major climatic impacts all over the world." (10)

More recently, an international workshop on energy and climate held in the Federal Republic of Germany concluded in the preface to its findings that "in the decades ahead, decisions have to be made to reduce or avert the impacts of climatic change before all the answers have been obtained. Although a climatic impact assessment program is faced with many uncertainties, it nevertheless has to be started now, because society cannot afford to wait until all variables are quantified to the satisfaction of all parties involved." (11)

Finally, I conclude this selective review of a number of the many bodies of experts calling for long-term physical, biological and social

research on various aspects of the carbon dioxide/climate problem with the findings of the joint World Meteorological Organization/International Council of Scientific Unions/United Nations Environment Program Group of Experts meeting held in Villach, Austria in November 1980. Among their findings were the following:

> Uncertainty characterizes many aspects of this complex environmental and social problem. This has given rise to considerable speculation that varies all the way from fears of impending disaster to the belief that there is no problem. The question has been examined by several responsible organizations in recent years and it is now clear that an inherently international issue involving potentially controversial and divisive aspects does exist. Moreover, a scientific problem of a global nature is involved and an international effort is necessary to illuminate the several scientific aspects that must be resolved to assess the magnitude and character of the issue. Regardless of the eventual importance of the carbon dioxide problem, research on as many components have applications to other major scientific and social questions...
>
> A major international interdisciplinary research effort is necessary to develop a set of impact scenarios based on extended sets of data not now available so as to deal successfully with uncertainty and to prepare a management plan of action adequate to cope with likely impacts. It is essential that the research proposed here be undertaken as a matter of urgency so as to put on a firmer scientific basis any intergovernmental action that may be required to accommodate the potential situation with which the world has not yet been confronted. It must also be emphasized that even a major research effort can never remove every uncertainty....
>
> A useful framework for study of economic and social impacts might be the development of comprehensive and internally consistent

> scenarios of possible future socio-economic development, energy and land use patterns, CO_2 levels, climate and the implications for agriculture and other economic sectors....
>
> The function of scenario analysis is not to attempt to predict the future: the future is unknown and probably unpredictable. Instead, scenario analysis is a tool that may help us to choose appropriate policies by making possible the exploration of the implications of alternative actions. Development and discussion of these scenarios by international and interdisciplinary expert teams might be an important mechanism for building a consensus on the major scientific and policy issues in a global community of physical and social scientists. (12)

Note the call for internally consistent sets of physical, biological and social scenarios with which to analyze the CO_2 buildup and its possible impacts. Precisely such a conclusion was reached after a number of years of investigation by a large panel of interdisciplinary scientists involved in the American Association for the Advancement of Science/Department of Energy, Carbon Dioxide Effects Research and Assessment Program. This program began with emphasis on physical science, and to a lesser extent, biological science, with a meeting held in Miami in March 1977. Although no social scientists were present, the report from that group nonetheless had as one of its recommendations that "interdisciplinary studies of the dependence of our social systems on climate change should be initiated." (13) That recommendation led to the Annapolis Workshop referred to earlier in which 28 papers and more than 100 interdisciplinary scientists and government officials met—under the general chairmanship of Roger Revelle--to begin the process of flushing out the scope of research on CO_2 impacts questions. Phase II of that effort was the assembly of five sub-groups, whose chairmen served as the Steering Committee for the overall

AAAS/DOE CO_2 impacts effort. Each group commissioned a limited number of scholars to write short papers on focused and tractable research issues, and the Steering Group then collated these and distilled from them relatively few research recommendations. In December 1980 the results were published as the thirteenth document in this DOE program series. Ironically, at almost the same time of the international meeting of experts in Villach, Austria, this AAAS/DOE report proposed as its highest priority that research on integrated scenarios be undertaken. The report states:

> The physical, biological and social sciences will be involved in answering important questions about possible CO_2-induced climate effects and scientists from each of these areas should participate in defining the situations of interest. While fundamental, isolated investigations of fluid dynamics and of social psychology, for example, would eventually strengthen those disciplines and thus promote better understanding of many aspects of the CO_2 issue, progress would be very slow. Much time can be saved by targeting and integrating the research. Since there are important feedbacks among atmospheric and ocean dynamics, marine and land biota, and agriculture and energy use, the CO_2 situation can best be defined via an integrated picture--that is, a scenario. (14)

At the urging from the Department of Energy, the American Association for the Advancement of Science prepared a proposal to perform such integrated scenario analyses. I myself had submitted, with my colleague William Kellogg, a small proposal to DOE to sponsor a workshop to examine the climatic component alone, hopefully as input for an integrated scenario exercise. In addition, the World Climate Program, whose impact assessment task is concentrated in the United Nations Environment Program and the World Meteorological Organization, was cognizant of this AAAS proposed U.S. research effort. Although no formal commitments were made to my

knowledge, responsible officials of the World Climate Program had anticipated that part of the U.S. contribution to the World Climate Impacts Program would be the conduct of integrated scenario analyses, as suggested by Phase II of the DOE research report and proposed by the AAAS to DOE in 1981. Moreover, I am aware of several informal conversations in which plans were being drawn to have an international meeting in the summer of 1983 to present to the world scientific community the results of the DOE-sponsored U.S. efforts in order to obtain criticism and to enlist collaborations for further work.

Unfortunately, I believe, the AAAS proposal met with an apparent policy change at the Department of Energy in the spring of 1981, and the status of this high priority effort is now, I understand, in limbo. So, too, are some international planning efforts for a workshop to review the output of this proposed research. It is my hope that this hearing will help to clarify the standing of future research efforts dealing with the full range of potential impacts on the environment and society from the advent or prospect of CO_2 increases, as mandated in the National Climate Program Act and called for by numerous independent assessment bodies. Moreover, if the Department of Energy is no longer willing to retain its status as a "lead agency," for which it had been committed in a recent National Climate Program Plan, then I would hope in addition that the Committee on Science and Technolgy would be able to work out alternative administrative mechanisms by which this important component of both U.S. and international climate programs could be carried out.

I greatly appreciate your consideration of my views on this issue. However, it is perhaps more appropriate to cap this testimony with the words of one of the Committee members, Congressman Brown:

> In summary, even if it turns out that we are incapable of averting a CO_2-induced crisis, or if no such problem emerges, we still will benefit from attempting to address the problem. In the long run, climate change is inevitable, and any improvement in our ability to deal with its impacts will be valuable. The obstacles to meeting the challenge proposed by the CO_2 problem are enormous, but the rewards that can be derived from working on the problem are also great. Can we really afford to give the problem anything less than our best try? (14)

REFERENCES

1. Summary of remarks by Congressman George E. Brown Jr. before the American Association for the Adancement of Science/Department of Energy, Workshop on "Environment and Societal Consequences of Possible CO_2-Induced Climate Change," Doc. No. 009 of the "Carbon Dioxide Effects Research Assessment Program," No. CONF-7904143, October 1980, p. 123.
2. Ad hoc study group on carbon dioxide and climate, Carbon Dioxide and Climate: A Scientific Assessment, Climate Board, U.S. National Academy of Sciences, Washington, D.C., 1979, 25 pp.
3. An the Assessment of the Role of CO_2 on Climate Variations and their Impact; Joint WMO-ICSU-UNEP Meeting of Experts, Villach, Austria, November 1980. World Meteorological Organization, Geneva, January 1981, 29 pp.
4. This figure was taken from Schneider, Stephen H. and Londer, Randi S., Weather Permitting: Our Physical, Biological and Social Links to Climate, Sierra Club, San Francisco, CA (in press).
5. Schneider, Stephen H. and Chen, Robert S., "CO_2 and Warming and Coastline Flooding: Physical Factors and Climate Impact," Annual Review of Energy, Vol. 5, 1980, pp. 107-140.
6. National Climate Program Act, Public Law 95-367, September 17, 1978.
7. Report of the International Workshop on Climate Issues, International Prospectus on the Study of Climate and Society, Climate Research Board, National Academy of Sciences, Washington, D.C., 1978, 3 pp.

8. The World of Climate Conference, Geneva, 12-23 February 1979, WMO-No. 537, World Meteorological Organization, Geneva, Switzerland, p. 716.

9. Primer on Climatic Variation and Change, printed for the use of the Committee on Science and Technology, U.S. Government Printing Office, Washington, September 1976, p. CRS-6.

10. Panel on Energy and Climate, Energy and Climate, Geophysics Research Board, National Academy of Sciences, Washington, D.C., 1977, p. IX.

11. Interactions of Energy and Climate, ed. by W. Bach, J. Pankrath and J. Williams, D. Reidel Publishing, Dordrecht, Holland, 1980, p. VIII.

12. See ref. 3.

13. Workshop on the Global Effects of Carbon Dioxide From Fossil Fuels, No. 001 of Carbon Dioxide Effects Research and Assessment Program, CONF-770385, United States Department of Energy, Washington, D.C., May 1979, p. 6.

14. Environmental and Societal Consequences of a Possible CO_2-Induced Climate Change: Our Research Agenda, Vol. 1, No. 013 of Carbon Dioxide Effects Research and Assessment Program , DOE/EV/10019-10, United States Department of Energy, Washington, D.C., December 1980, p. IV-I.

15. Ref. 1, p. 125.

STATEMENT OF LESTER LAVE, SENIOR FELLOW, ECONOMIC STUDIES PROGRAM, BROOKINGS INSTITUTION

Dr. LAKE. Thank you. You gentlemen are taking time out of what must be the most frenetic session that Congress has gone through in this century to come and learn about CO_2.

There are two reasons why this subject is so fascinating. CO_2 represents both a long-term critical problem and a symbol. Roger Revelle told us why it is a long-term critical problem.

As we look to the next century, probably the only global effect of our current actions that we can foresee with some certainty stems from carbon dioxide released by burning fossil fuels and clearing forests.

Mr. SCHEUER. Would you include acid rain as a part of that problem?

Dr. LAVE. We don't know enough at this point to be certain. The other reason for concern about CO_2 is the symbolic value. As we look toward the distant future, we know there are many factors that are going to affect us profoundly, almost none of which we can do more than guess about. One can only look to the future and hope the next generation is smarter than we are.

However, CO_2 is different because we understand the nature of the problem. We understand something about what the physical effects are going to be and we understand how we can do something about them. Carbon dioxide stands as a symbol now of our willingness to confront the future and especially of our willingness to consider problems that will not be manifest until after the next election.

It will be a sad day when we decide that we just don't have the time or thoughtfulness to address those issues. I am disheartened by some of the changes I understand have taken place in DOE indicating they don't think they have the mandate, ability, or resources to address the CO_2 problem.

Let me try to hit a couple of highlights as to why I think there are some critical research needs that don't seem to be addressed in the proposed DOE program. I will be brief, since my three preceding colleagues have done a very nice job.

The first is that it simply doesn't make sense to concentrate—or possibly limit—research on the carbon cycle and on fluid dynamics. However wonderful it looks to say we need to get answers to the physical questions first, then we can deal with the rest, that is not the way science works. If you wanted to get definitive answers to the atmospheric physics, then you might have to wait a very long time.

Those are very complicated issues; a reductionist approach doesn't make sense. DOE might recommend that research moneys be put exclusively into particle physics because if we understood that well enough, then we would understand chemistry, and eventually biology, and eventually everything else; thus it is "wasteful" to put money into other kinds of research.

However, there are many questions on many levels. It is not enough to look at some fundamental inquiries and neglect every other aspect.

Steve Schneider laid out very nicely a conceptual way of looking at the problem of starting from emissions, then going on to look at the atmospheric and oceanic effects, going on then to look at marine and terrestrial biology, to agriculture and silviculture, and then to human effects.

That logical process can either be pursued serially, or it can be pursued in parallel. Pursuing it serially has some validity in that if we have no idea of what the effects of carbon dioxide are on the atmospheres and the oceans, then how in the world can you do anything else?

However, if we wait until we get definitive answers as to the effect of carbon dioxide on the atmosphere and the ocean, we will not get to the second step in time to make adjustments.

A serial approach won't get us answers in time; we need a parallel approach.

Another reason besides timeliness is that the laws governing atmospheric physics and the oceans are well known. However, the equations are so complicated that they cannot be solved; they can only be approximated using complicated computer codes. To get useful results, one has to know rather precisely and narrowly what regime you are working in.

You can't search through all levels of carbon dioxide to discover each set of effects. You have much more power if you can search within a narrow range. In order to know the appropriate narrow range, you have to know not just generically that human beings burn fuels and cause atmospheric CO_2 to increase; you have to know approximately how much and when in order to be able to get better answers to these.

That means that instead of trying to start at the beginning and go through to the end slowly, that a better way of approaching this is to try and encircle the problem completely and then to close in from all sides.

It is better to have a series of successively better approximations to the whole problem than to isolate one part and concentrate on it. We learned this in the AAAS effort.

All of the people so far have said something about scenarios. Let me just clarify that a little bit since that term has been used by people with wildly different notions. What we meant by scenarios is not a movie script, but rather a set of carefully stated assumptions and their implications. A scenario is a series of "What if?" explorations of an issue: What if atmospheric emissions of carbon dioxide are so much? The conclusions follow from these assumptions. The value of the scerarios is that, when you circle all the way through, you find that there are some large economic and social implications of the implied climate and biological changes. These economic and social implications will change behavior, particularly the emissions rate of CO_2. If the assumed rates of economic growth and of CO_2 emissions are incompatible with the CO_2 effects, then the scenario is internally inconsistent and could not occur.

Among the internally consistent scenarios, one must evaluate each for desirability, plausibility, and likeliness of occurance.

One of the things that was most heartening about the AAAS effort was the ability to get quite noted experts in each field to sit down and go through this painstaking process of not only under-

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standing the language, but also the thinking of people in other areas. We found ways to work together to encompass this problem and get some better answers to it.

One last important distinction is between the physical effects and how we adapt to them. We should not regard changes in the environment as being only adverse. Many changes are highly beneficial. Whether a change is adverse or beneficial has much more to do with us and our institutions than it does with the physical environment. You can have the most beneficial kind of environmental change, and it can mess us up if our institutions are not functioning well.

Mr. SCHEUER. Can you give us a list of the kind of changes that might be beneficial?

Mr. LAVE. Any change can wind up being beneficial if our institutions are working well, and we have some idea of how to cope. For example, suppose the climate gets warmer at a particular place. Then either that can be an adverse change, if it turns out that we stupidly proceed to plant exactly the same strains, using exactly the same cultivation and irrigation practices as in the past. That will be a disaster.

If, on the other hand, we are smart enough to use plant genetics to get more suitable strains and modify our agricultural practices, then we can produce more.

I don't want to be Pollyannaish and say emitting CO_2 is wonderful and we will do great things with it. I do want to say that we are not going to be able to do much about much of the CO_2 emissions.

Given the attractiveness of fossil fuels, we are not going to stop using them in the next few decades. Thus, we had better worry about how adaptable are our institutions. Those kinds of social questions, the ones that allow us to take advantage of or at least not be terribly adversely affected by these changes, are the nature of the problem that DOE seems to be turning its back on. They seem to regard it as a narrow technological problem of what are the effects going to be on the atmosphere. I think that that is far too narrow to allow us to get insights into this problem. Furthermore, this technological view is too narrow to allow us to confront the general kind of future problems that I started off with.

We seem to be turning our backs on the carbon dioxide problem, waving our hands and assuming there is some simple technological solution that we can get at by studying the atmosphere and the oceans and neglecting all else.

Certainly we need to study the atmospheric physics and oceanography, but we also need to study the biology, agronomy, economics, and sociology.

Thank you.

[The prepared statement of Mr. Lave follows:]

Testimony
before
Natural Resources, Agricultural Research
and Environment Subcommittee

House Science and Technology Committee

Lester B. Lave
Brookings Institution
July 31, 1981

Carbon dioxide is unlikely to be the most important problem faced by the human race in this century, or even in the first half of the 21st century. Although atmospheric concentrations of carbon dioxide are likely to produce the first major effects of human activities on the entire planet, these effects are likely to be of small consequence compared with those of war, especially nuclear war, population growth and composition, and even the economic relations among nations, at least over the next century.

But among all these issues, carbon dioxide is unique in being something we can understand, control, and where there is sufficient time, to act. It is an archetype of policy research about the future and a symbol of the human race's ability to begin shaping its destiny, rather than simply reacting to circumstances. If the race cannot "solve" the nexus of carbon dioxide issues, what hope is there for other future issues about which we know less and which are more difficult to control? At the same time, by demonstrating our ability to map out the problem and solution strategy, to communicate with other nations, large and small, about the problems and strategies, and to implement a solution, Earth's inhabitants will have taken a major step toward working out other major issues.

There is a simplistic view that carbon dioxide represents two basic and one applied research problems: the carbon cycle, global fluid dynamics, and nonfossil energy technologies. Certainly, more needs to be learned about each of these topics, but none speaks to the effects of increased atmospheric concentrations of carbon dioxide, the design of policies to deal with these effects, and the implementation of these policies. This view implies that the only role of government is to do basic research, after which the market place or our social institutions will have to intuit solutions.

Conceptually, the analysis must begin by specifying alternative time paths of carbon dioxide emissions and the factors that influence these emissions. Next, these emissions must be transformed into a time stream of atmospheric concentrations, or other sinks, and of the resulting direct changes in the atmosphere and oceans. There follows direct effects on marine and terrestrial biota, and finally, potential effects on humans and their agriculture and sylvaculture. Carbon dioxide emissions and all the effects are potential because humans can react by changing the use of fossil fuels, the locations of their activities by irrigation and by planting new varieties in each place. Humans are capable of perceiving changes and inferring their cause; they can modify their behavior to remove the cause or lessen the effects.

Some research managers have thought of carbon dioxide research as a serial process, where the atmospheric and oceanographic effects must be understood before investigating the direct biological effects and effects on agriculture. Research on the effects on human

activities and the feedback effects on human behavior (and thus on emissions) would await the completion of the physical science research.

This serial approach makes no sense for two reasons. The first is that it would take decades to get better answers to the atmospheric and oceanographic questions. Even assuming we did not wait until the physical science research was completed, it might be half a century before any of the behavioral effects were studied; all solutions could well be precluded before the research was initiated. If that approach makes sense, I propose directing all funds into particle physics since, if we could understand this area sufficiently well, we might obviate the need for all other physical science research.

The second reason why this approach makes no sense is that atmospheric physicists, oceanographers, biologists, and agronomists can make the most precise and powerful statements when they are able to focus their attention narrowly. For example, if the relevant range for atmospheric carbon dioxide were twice the current level, this should be the focus of research, enabling more powerful statements than if climatologists had to investigate a wide range of atmospheric concentrations. The relevance of picking out a narrow range for attention is even more important in examining the effects on biota. This fact means that it makes more sense to work through the issues completely in a rough fashion so as to characterize the relevant range, and then to narrow the range as research proceeds. Indeed, this method may be the only one to produce reasonable answers, if, for example, the atmosphere is sufficiently complicated to model that one can only get approximations within a range in lieu of completely working out the

properties of a wide range of carbon dioxide concentrations.

A major AAAS proposal was precisely to work through the set of issues parametrically, using a team composed of experts from each discipline. The team was to have attempted to work out a set of "scenarios" or carefully specified, internally consistent paths of carbon dioxide emissions and their consequences, including the feedbacks. I believe that this effort would have made a major contribution to our understanding of carbon dioxide effects, to helping others understand the nature and magnitude of the problem, and to setting out priorities for research.

I would now like to explore briefly some research on the effects of climate change induced by carbon dioxide. The most important insight is that change is not necessarily bad. In particular, a world with warmer temperatures at the poles and more carbon dioxide should produce more plants. It should also lead to more problems with weeds and insects. The net effect on humans will depend most directly on our ability to recognize the need for change and to adapt by changing cropping patterns, introducing new varieties, and changing practices such as irrigation. We have sufficient knowledge of plant genetics and agronomy and of irrigation so that adverse effects could be minimized and positive effects made to predominate. Whether this occurs will depend on society's ability to focus its knowledge on the problems and opportunities, and change behavior. In other words, it depends on whether our institutions are functional or dysfunctional.

From the middle of the last century, our institutions were marvelously efficient in finding solutions to problems; both the nation's and individuals' incomes grew rapidly. In the last decade, our institutions have not functioned well and there have been severe social and economic strains. The key question for carbon dioxide is whether our institutions will be effective in solving the problems induced by carbon dioxide.

During the next century, our nation and the world will be beset by a host of problems; will our institutions be part of the solution or part of the problem? It is likely that climate change will pose problems similar to other social problems; making our institutions functional with respect to climate change should help us adjust to other changes and vice versa. Thus, analysis of the carbon dioxide challenges are one way of focusing our scientific attention on a more general set of challenges. While the Department of Energy's chopping up and discarding of an integrated research program for carbon dioxide is a social loss, the greater loss is refusing to begin thinking systematically about the wider global challenges. Are we preparing for the vast, rapid changes that have been occurring and will accelerate in the future?

Mr. SCHEUER. Thank you very much, Dr. Lave, for your thoughtful and stimulating testimony.

I regret we scheduled two panels here today, because we could easily take another several hours questioning these witnesses. However, we plan to work straight through until we finish the second panel.

I am also quite certain we are not going to have enough time, even if we devote another hour to this panel, to ask all the questions we would like to ask. So, I am going to ask all of you if you would be willing to respond to written questions, which we will then include with your answers in the record. We will hold the record open for 10 days or 2 weeks, and I would ask all my colleagues, if they have written questions, to give them to our staff, majority and minority, so the two staffs can collate the questions and eliminate the duplications and overlappings. You can assume, when you leave here today, your job isn't quite finished.

I would also like to introduce our minority colleague, Mrs. Claudine Schneider, who is one of the most hard-working members of this subcommittee.

I am going to ask just a couple of questions to all of the panel, and then I am going to yield to my colleagues. We will plan to work with this panel until 12 or 12:15, and then we will address the next panel until at least 1:30.

Let me ask all of you, which international agencies are active in evaluating this whole question of CO_2; which agencies if any are playing the lead role; and, last, is there any need for a new agency to produce either the knowledge base or the forum for policy discussions on the emerging threat?

Is there need, for example, for a global environmental monitoring presence?

In a trip that I took to Europe with Congressman Udall over Easter, we asked the Germans, the British, the French, and the Belgians, whether they felt there is a need. I am sure that Canada and the Scandinavian countries feel there is a need, particularly in the area of acid rain. That is one question I would like any of you who are interested to respond to.

Mr. REVELLE. Mr. Chairman, there are several international agencies that are seized more or less with this question. One is the World Meteorological Organization, which, in cooperation with the International Council of Scientific Unions, is initiating and beginning to carry out something called the world climate program. It has four parts to it: climate research, climate data, climate impact, and climate application, the use of climatic information.

This is a pattern, first developed during the so-cal[illegible] Global Atmospheric Research Program, of cooperation between world scientists as represented by the International Council of Scientific Unions and the intergovernmental agency, the World Meteorological Organization.

As far as impacts are concerned, the United Nations Environment Program, with headquarters in Nairobi, has a rudimentary system of impact monitoring and is thinking about doing more.

My own belief is that at the present time no separate organization would be either necessary or desirable, but that a good deal of national support needs to be provided for the world

climate research program, and, particularly, as far as I am concerned, for the oceanographic aspects of that program, which are under the auspices of the Intergovernmental Oceanographic Commission of UNESCO and the Scientific Committee on Ocean Research of the International Council of Scientific Unions.

Mr. SCHNEIDER. I agree with Roger Revelle, we don't need a new institution, and what we really have to do is participate with a variety of other nations and international groups in research. This goes on informally. One example I know of is the International Institute of Applied Systems Analysis, near Vienna, whose whole funding future is in some question because it comes in part from the NSF.

One of the things it does is serve as an international forum on global issues or systems issues such as CO_2. Informally, I know now that a number of people there have been planning a world workshop in the summer of 1983 to discuss the results of the AAAS integrated scenario assessment program, and I just got an urgent cable from a colleague, saying, "What do we do; we understand it isn't going to happen?"

A lot of the way the United States participates in international scientific work is through the kinds of informal contacts where scientists going to meetings mention what they are doing and then world groups organize meetings around what they expect to be that U.S. program. There has been some frank concern about the reliability of the United States as a participant in world scientific issues by just not doing its own research. There is a German program and a European program on CO_2, and the most important thing is to keep informal contacts going and attend the international meetings which crop up. I hope they will continue.

Mr. SCHEUER. Is there a need for a coordinating focus, some agency or institution, to pull it all together and set the agenda for future action? Where is the leadership?

Mr. REVELLE. There is a world climate impacts program, and it has a CO_2 thrust. That was through the World Meteorological Organization initially, but it has been now spread to involve UNEP and the International Council of Scientific Unions. It is still mostly at a scientific level, and I include physical, biological, and social sciences in that.

With regard to direct policy questions, scientists have debated whether there should be a ministers' meeting. There was a general feeling among the scientists that this was premature in that people tend to confuse uncertainties and end up arguing all over the place. It may be premature to have a formal organization looking directly at policy questions, but certainly we want to see continued support for the international scientific effort and perhaps even some ministerial interest so that decisionmakers can at least keep up.

Mr. SMAGORINSKY. I would like to add something to Steve Schneider's point. Actually, the World Meteorological Organization and UNEP, both of which are U.N. organizations, together with a nongovernmental organization, ICSU, have been discussing, at the urging of the international community, the establishment of a standing assessment committee that would continually be monitoring what is being learned; more or less the international counter-

part of what I described earlier in connection with the National Academy of Sciences assessment study. Such an international committee would also make recommendations on what should be done in all facets of the CO_2 question, the research on the physical system, impacts, data requirements, and so on.

Data, of course, would include the whole question of monitoring since it inherently requires an international effort. It is an impossible task to decide to monitor everything everywhere.

Right now, the international community is at the stage of trying to identify what is worth monitoring. That is not an easy matter. They are trying to identify significant indices that can give us some warning.

The effort to establish an international assessment group has floundered for about a year and a half. There have been problems of international rivalry between international organizations, but I hope this gets resolved quickly because everybody realizes that it is in all nations' interest to do it and to do it well.

Mr. SCHEUER. After you decide what is worth monitoring, then you have to give political leaders some indication of the magnitude of present impacts. They are very hard to determine from year to year. There are more than four different trends you can see there. At what point, looking into the future and seeing the magnitude of future impacts, does it become cost-effective to take present measures to either control or mitigate deleterious consequences that may take place 10, 20, 30 years from now?

Mr. SMAGORINSKY. What we need is a continuous long-term record in order to be able to detect a cumulative change.

Mr. LAVE. I think CO_2 is a serious problem. Some of the technologies that we are pursuing with respect to synthetic fuels don't make any sense if this is the case.

In situ coal gasification produces large amounts of CO_2 per Btu of energy compared with other technologies. If we take the CO_2 matter seriously, then we would eschew such CO_2 intensive technologies.

A more sensible energy policy need not be anything so radical as doing away with fluid fuels or changing our transportation network. There are marginal technologies like in situ coal gasification, which look only marginally attractive, if at all; if you add on even a tiny penalty for the CO_2 they put out, they become unattractive technologies.

That is why I think this has to be in DOE's lap. They can't say: well, sometime we will get answers to this. We have to get some answers now, because we are pursuing energy policy now; we are having vast effects on the future levels of CO_2 through our curent energy policy.

I think that the natural home for this research is in the Department of Energy. However, the Department of Energy must take it much more seriously than they seem to have been doing lately.

Mr. GORE. Will you yield?

Mr. SCHEUER. Of course.

Mr. GORE. By the same analysis, you could be led to conclude that increasing the options for nuclear power and keeping alive the

option of breeder technology would be more justified by that amount, would it not?

Mr. LAVE. It certainly is true. It was mentioned earlier in the direct testimony that when we look to the future, you want to have a lot of options open in terms of energy technologies, in part because it takes a long time to develop a new option. You may not want to pursue one of them right now for many kinds of reasons, but it is really nice to have those options be open.

Mr. GORE [presiding]. The subcommittees will come back to order.

Dr. Revelle, during your presentation you commented on the 1974-75 recession and I discussed with you some graphs briefly during the break.

Several months ago, when Jim Schulman of my staff pointed out this middle graph to me I went home that evening and came to the conclusion that if the relationship between fossil fuel consumption and CO_2 was as firm as the hypothesis which has brought us here today would have it, then it ought to reflect the fluctuations in worldwide consumption of fossil fuels.

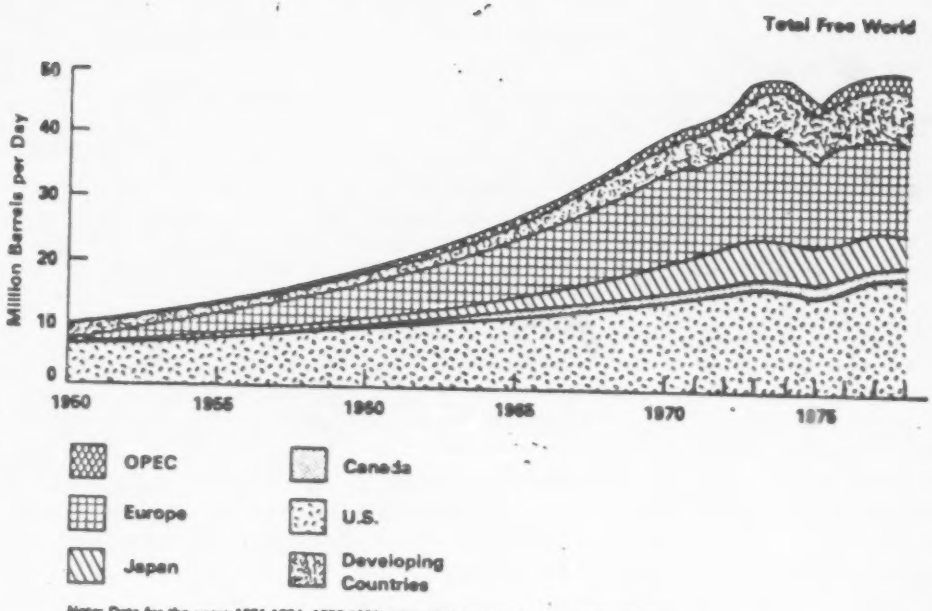
As a member of a couple of energy subcommittes, I have noticed over the years that the most important factor affecting fossil fuel is the economic activity in the world and when you have a worldwide recession then the consumption patterns are dramatically affected.

I took the trouble of getting a chart—it is not reproduced as an overlay on this one; time prevented us from doing that, but I provided you with the graph which I will supply for the record entitled "World Oil Apparent Consumption, 1950 to 1978," and if you connect the peaks on the middle chart to the left and compare it with the graph on world oil consumption, the rise in the rate of consumption during the years 1971 through 1973 is exactly reflected in the CO_2 measurements and the dramatic decline in world oil consumption during the period 1974 to 1975 is also reflected and the picking back up from 1976 onward is also reflected.

It may be a coincidence, but it certainly seems to me to be an interesting piece of evidence.

Do you have anything to argue against that?

[The graph mentioned follows:]



World Oil Apparent Consumption, 1950–1978

Source: Department of Energy

Mr. REVELLE. No, I don't. What we have tended to think about these fluctuations in the curves—they occurred not only then, but all the way through the years from 1957–80, is that it may be due to the southern oscillation which affects the temperature, or which is a reflection of the changes in temperature in the tropical Pacific.

I would like to congratulate you on your research.

Mr. GORE. Thank you, Doctor. I think I had better move right on to the next witness quickly.

Mr. REVELLE. I would point out these are very tricky things, to try to establish correlations like this, as you would know very well.

Mr. GORE. The reason it was intriguing to me is that one of the areas of uncertainty in Dr. Schneider's inverted pyramid is how much of the effect is due to fossil fuel consumption rates and how much is due to deforestation; how much is due to the relative absorption of CO_2 in the biosphere, in the oceans, and if a variation in fossil fuel consumptions does have as marked an effect as this correlation would appear to indicate, then that area of uncertainty is somewhat narrowed.

I was noticing in Dr. Smagorinsky's statement the following sentence:

> The consensus on the nature and magnitude of the problem has remained remarkably constant throughout this long worldwide process of study and deliberation.

Now, that is really a pretty good summary of the reason for this hearing, as I see it. The problem hasn't gone away. It hasn't gone away and the shaky hypothesis which began on the fringes of science has now worked its way into the mainstream of scientific thought.

Let me ask the panel whether you are aware of any reputable scientist in the atmospheric sciences who takes the position that this whole thing is just a wild delusion?

Dr. SMAGORINSKY. There have been some recent studies. Let me first of all confirm what you quoted me as having said. Except for a very early study which came up with a 9-degree change, virtually all other studies have come up with numbers of the order of 1 to 5 degrees for a global temperature increase due to a CO_2 doubling. There have, however, been some studies in the last few years since the Charney report, by very creditable scientists, that have challenged that.

They used simple models, but probably models that were too simple, to come to the conclusion that perhaps the response might be in order of magnitude less than what I just quoted—namely, that is tenths of a degree for a global temperature increase.

I think there is general agreement, and this will be dealt with in the report by the Academy, that these more conservative results probably are not correct.

Mr. GORE. The effect to which these studies point has to do with our primitive understanding of cloud systems?

Dr. SMAGORINSKY. No, actually the differences had to do with not properly taking into account the influence of the atmosphere's reaction in addition to that of the Earth's surface. When the heat balance at the surface is considered in isolation, you get a small response.

Mr. GORE. Those challenges over time have been somewhat discounted and the developing consensus has not really been greatly affected by that dissent?

Dr. SMAGORINSKY. I would say so.

Dr. SCHNEIDER. I agree. I would add one footnote. If you ask for a global consensus of scientists before Copernicus as to whether the Earth is the center of the solar system, we would have had a problem. However, we have gone a bit beyond that, but we could always be wrong.

Present dissenting people may prove by accident to be partially right, but not by any argument they have now used.

It is conceivable something we haven't thought of will come along, but there is one very strong piece of empirical evidence which suggests we may be on the right track and that is the difference between the winter and summer.

The fact that the winter is cold and the summer is warm, when the amount of energy from the Sun increases and decreases with seasons, tells us the climate responds if you force it. We haven't had any way to directly verify our models, because we have no known precedent when carbon dioxide was radically different from present, though there are some hints now that there are but we have no very good proof of that. Instead, we have to use surrogates and the one we use most is the seasonal cycle. In fact, these very same models which predict the CO_2 increases predict well the difference between winter and summer, especially some of the models developed in Dr. Smagorinsky's laboratories and some we and others have developed. That gives us confidence that we are not on another planet with regard to these models.

Mr. GORE. So the amount of uncertainty is indeed narrowing.

Mr. Lave, did you want to comment on that?

Mr. LAVE. I have no comment.

Mr. GORE. Give me, if you will, the simple reasons why the temperature increase at the poles is so much greater.

Mr. SCHNEIDER. I also want to hear this simple reason.

Dr. SMAGORINSKY. It has to do with the fact that we have snow cover at the poles. At the snow perimeter the reflectivity or albedo of the Earth's surface changes rapidly and, most important, by a huge amount.

In addition, near the polar regions, the part of the atmosphere that mixes is shallower than elsewhere. Therefore, heating resulting from an increase in CO_2 and its greenhouse enhancement will melt some of the snow. At the retracting snow perimeter, the surface reflectivity is sharply reduced, more of the sun's radiation is absorbed by the Earth and then reradiated to heat the troposphere. The Earth-atmosphere temperature increase at the latitude of reduced snow perimeter is thus accentuated—a positive feedback—so that the heating is confined to a narrower depth and the surface temperature response is even greater.

Both of these act together. It is known as the snow-albedo feedback.

Mr. GORE. I appreciate the explanation.

Now, looked at from a national point of view, by doing so I don't wish to deny the global perspective which is so obvious but in assessing the importance and severity of the problem for us, I think it is not particularly useful to average in the good effects with the bad effects and conclude that everything comes out in the wash.

If the effect is real, as it appears to be to the censensus of scientists who have looked at it, how likely is it that our grain belt will shift northward to Canada?

Mr. REVELLE. One of the problems here is that it can't shift northward because of the differences in the soil. It is easy enough to talk about a warmer climate in Canada, but the soils there are not the rich black soils of Iowa; they are acid forest soils and they are liable to be very much less fertile and productive.

Mr. GORE. How likely is it that our grain belt—that we will lose our grain belt?

Mr. REVELLE. I wouldn't say it is by any means a certainty, but it seems to me it is very likely we will have to make major adaptations because of a considerable warming of the temperature. Right now in the Corn Belt the optimum climate for corn is a little bit cooler than the average climate. The corn yields are greater when the summer temperature is a degree less than the average.

If you go up by 6° C., about 10° F., if you are going to grow corn there it will have to be a different kind of corn.

Mr. GORE. By the same token, the southwest of the United States will become more dry and arid?

Mr. REVELLE. If you take Flohn's model, the drying would be concentrated around latitude 40° N., which goes right through northern California, right through the Missouri and Illinois area, right across to the Atlantic, about the latitude of Pennsylvania or Philadelphia.

That would be the area of greatest drying if Flohn's model is correct, as well as a relatively large increase in temperatures in the United States.

The further north you go, the greater the increase in temperatures.

Mr. GORE. In the news today we read a lot about the policy toward illegal immigrants from Mexico. If this is true, it appears that Mexico is coming out ahead too.

Mr. REVELLE. Mexico might be a little better off if you take Flohn's model.

Mr. SCHEUER. Why would that be?

Mr. GORE. The reason is the moisture patterns at different latitudes are affected in different ways. Some gain moisture and some lose moisture and they do not exactly track the temperature variation patterns.

There is a different combination, a different intersection of the two patterns at each latitude.

Mr. REVELLE. Professor Flohn projects a 20-percent increase in precipitation, at latitude 20° N., which goes right through the middle of Mexico, in contrast to a decrease in precipitation, at latitude 40° N., which goes through the middle of the United States.

This is clearly just one model. Nevertheless, it is a very disturbing model and, as I said, particularly for the river flow, the increase in temperature and a decrease in precipitation might radically change the volume of flow of a river like the Colorado.

Mr. GORE. One of the options that was listed was to do nothing. It seems to me that ought to be rephrased because we are creating the effect, or helping to create the effect by continuing the consumption patterns that we are now pursuing.

I think it is important at this point in our history to recognize the magnitude of the effect on our global environment of industrial civilization's pattern and that ought to lead us to reevaluate the range of options that are available to deal with this.

If it is real and if the areas of uncertainty continue to narrow, then I believe we ought to discard all of the smaller options of trying to adapt to it like maybe giving some travel tax credit to those people in Florida who have to move from their homes or adapting agricultural policy in Nebraska to come up with sand flea farms and rather to concentrate instead on looking the large problem straight in the eye, recognizing its global cause and selecting the one obvious solution for the problem if it is determined to be in fact real, which is a rather dramatic change in the energy consumption patterns worldwide. It seems pretty obvious that is the appropriate response, but the areas of uncertainty are still large. What I mean by that is, accelerating a moving away from fossil fuel. It is just obvious that that is in fact what is causing the problem. If the cause and the effect relationship is real and if the impacts of the development are of the magnitude that have been described by this panel today, then the response appears to be obvious.

Dr. SCHNEIDER. I will comment briefly on that. Both Lester Lave and I were members of the same Academy of Sciences Panel on Energy, the Committee on Nuclear and Alternative Energy

Systems, and I was on the Risk Panel whose job it was to compare risks of various systems.

I thoroughly agree that the basic question of the mix of energy options is really what is behind the CO_2 problem and it is perhaps why it was first picked up by the Department of Energy. I think, by and large, my criticism of their latest possibility notwithstanding, the DOE has done a good job of following it through.

We have the fact that CO_2 is not the only risk of energy systems. There are other options but they have cost questions, social acceptability questions, questions of the safety of a plutonium economy and one has to weigh all of these obviously complex trade-offs in a gigantic picture.

The second is the time at which each risk or benefit comes about. One says the obvious solution is to go to nuclear——

Mr. GORE. I didn't say that. I said the obvious solution, if all of those areas of uncertainty are narrowed appreciably, the obvious solution is to move away from the current rate of fossil fuel consumption rather rapidly.

Dr. SCHNEIDER. Agreed. I certainly didn't mean to put those words in your mouth. I am glad they weren't there.

The most important point I wanted to get to is if it occurs 150 years down the line or 100 years down the line or 50, it is a very important difference. If the risks are far away we then can talk about what energy systems we use for transition. While I might be—and I am—very concerned about the idea of a plutonium economy in steady state, I might have a very different view about a transition use of nuclear, for example, if we were going to have another renewable energy source as our long term. The timing of the use of each energy supply is absolutely crucial in this question of the proper mix of options.

This is where the regional scenario issues come back again because the rate at which things change will tell us not only what are the possible impacts, but the way we could move toward new supply options at different times.

Mr. REVELLE. One thing to be added here, if you could use up all the oil in the world and all the known natural gas, you would probably not cause a doubling of carbon dioxide, it is the coal option that really makes the difference.

The total amount of carbon locked up in fossil fuels is somewhere between 5,000 and 10,000 billion tons. Ninety percent of that is coal. Ninety percent of the coal exists in three countries, the U.S., the Soviet Union and China and if the scenarios are right those are the countries that are going to be most affected by the CO_2 problem. It is a very interesting thing.

The effects will be felt most by the countries that can make the difference, by using or not using, exporting or not exporting coal.

Mr. LAVE. Could I follow that up a little bit? In the near term fossil fuels are so tremendously attractive worldwide that we are not going to give them up. We do have these difficulties, these uncertainties that you alluded to. It seems to me that it is likely to be the end of this century before we get a definitive judgment that these models are in fact predicting the effect of CO_2 correctly.

Nobody will incur the kind of cost necessary to give up fossil fuels before we have such definitive tests. If we look at the timing,

it will be the end of the century before we begin to get reasonably definitive tests.

At that point, even if the United States gave up all fossil fuels instantaneously, it would have relatively little effect on the world problem. All the other nations would have to be convinced. Some would be gaining, some losing by these temperature changes, and so not all of them would be willing in fact to go along with slowing down CO_2 emissions.

Any time we do anything internationally, it takes decades to get anything resembling agreement. Even after you get agreement, trying to go away from fossil fuels to some other source is extremely difficult.

Just putting the capital in place after you have the technologies all developed takes an enormous amount of time.

What I am saying is that surely we are going to wind up having a doubling in the atmosphere of CO_2 even given a vast concern today.

Just play through the scenario and there is no way we can stop short of that. So that means we are going to have vast kinds of climate changes. Thus, we are going to have to learn to adapt. Adaptation is made easier by knowing far in advance the nature of what we are going to have to adapt to. For example, plant geneticists need time to do their research.

I am not being sanguine about CO_2 effects, but I see no way to circumvent them.

Mr. GORE. But that is not the most intelligent response for civilization, is it?

Mr. LAVE. Given that we still have some uncertainty at the moment, it is hard to think about a justification of really major costs at this point, to use less fossil fuels.

Mr. GORE. The obvious near-term response is to seek a much more rapid elimination of the uncertainties involved.

Mr. LAVE. That is correct.

That is what we are here testifying about this morning.

Mr. GORE. Thank you, Mr. Chairman.

Mr. SCHEUER. Congressman Brown.

Mr. BROWN. I would like to follow on with this a little bit.

It seems to me that obviously one of the courses we should be looking toward is alternative options to the combustion of fossil fuels, particularly coal.

There are a number of options being explored in the area of research, including fusion, nuclear, and the various forms of solar.

I would just like to raise one question which was sort of stimulated by Roger's comments.

Under the present circumstances, what we have is a large drawdown in the world's fossil fuel supply, increasingly coal; a similarly large drawdown in the biomass resources of the globe due to deforestation, urbanization, desertification, various other things of that sort.

Roger, you suggested that the use of biomass as a fuel, as long as it was done on a replacement basis, made no net increase in the carbon dioxide balance in the atmosphere. The present situation is that the destruction of biomass is being translated into carbon dioxide in the atmosphere, but this leads to the assumption that if

we were to reverse our biomass policies and begin an aggressive reforestation program, use the net annual growth as fuel, we could perhaps both reduce our use of coal and by virtue of the net increase in global biomass we could reduce the carbon dioxide in the atmosphere at the same time.

In other words, we could make at least a minor effect on reversing the present trend lines. Now the only thing that bothers me is, I haven't the vaguest idea what kind of numbers we are talking about. I heard yesterday or the day before that there was a potential for increasing our production of energy from biomass, from somewhere around one quad up to as much as 8 quads with responsible policies.

I do not know what the overall capability in terms of equivalent amounts of coal, for example, are from increasing the net biomass resources. Has there been any information?

Mr. REVELLE. There has been quite a bit of thinking about that.

That figure of 8 quads is a figure provided by the Congressional Office of Technology Assessment. In terms of tons of coal, that amounts to about 250 million tons of coal, just for the United States.

Mr. BROWN. That is a substantial fraction of the amount of coal that we burn today.

Mr. REVELLE. Yes, but it is not a substantial fraction of our total fuel use in the United States. If you look at the less-developed countries which are in the tropics and where most of the remaining forests are, I reckon with the use of fast-growing trees like *Leucaena*, *Casuarina*, and *Sesbania*, which will produce up to 30 tons of dry wood per hectare per year, that all present world energy use could be accounted for by biomass grown on something like 400 million hectares, which is about one-tenth of the present forested area of the Earth.

What you would have to do is replace the existing tropical trees, which gives ecologists horrors, with these fast-growing trees, and harvest them on a regular cycle of about 4 or 5 years. What you want particularly is a tree like the ones I mentioned, which fix nitrogen so you don't have to fertilize the forest, as opposed to eucalyptus where you would have to fertilize.

Mr. BROWN. So you see the potential here of substantially replacing the coal utilization through utilization of these rapidly growing species of trees?

Mr. REVELLE. That is right. In fact, there is some movement in that direction already in the Philippines and in Hawaii.

The thing I guess I would like to emphasize here is that forestry is one of the most research-lacking fields there is; the reason is you get only one scientific result per generation, which is not enough for most scientists. We need somehow to greatly increase our research on every aspect of the use of biomass fuels, including how you convert them to convenient fuels like liquid fuels, as well as problems of tree diseases, problems of increasing photosynthetic production; just an infinite number of problems that need to be worked on.

If there is one kind of an institute that I think should be established internationally, it is a biomass research institute.

Mr. GORE. May I interrupt briefly to remind Dr. Revelle that he has an airplane to make. If you want to, direct one more question to him, or if not go to the rest of the panel.

Mr. BROWN. Roger isn't the only one that knows anything on the panel.

Mr. GORE. Thank you for being with us.

Mr. BROWN. Dr. Schneider?

Mr. SCHNEIDER. In the same connection back to our committee, as to biomass there were two limiting factors; one is the costs, therefore the rate which you can bring it in; the second is the world food problem again, the arguments you might have over building and managing an energy-agriculture when there are places which are having trouble feeding themselves. I do not think either one of them should be limiting.

We are again back to the rate problem. Just to give you an idea, Roger Revelle said 400 million hectares would be needed, and a standard figure for clearing a new hectare of agricultural land is $1,000 a hectare. What is 400 million hectares times $1,000 per hectare? You come up with $400 billion just to do the clearing. So you get an idea of the magnitude—you can't do that in one year, but if you can stretch it out, it looks better.

Again, what is the long-term renewable resource we are heading toward?

Whether or not to use coal or any other mix depends upon whether you think the end that you are heading to is worth taking some risks in the transition.

Mr. BROWN. Roger's figures make a point just in terms of strictly energy conversion. But looking at the broader question of curtailing the carbon dioxide problem without focusing on the production of energy crops, any biomass crop is going to have the benefit of taking carbon dioxide out of the atmosphere and to the degree that we could say double the amount of biomass on the globe, whether we used it for energy or used it for food would be immaterial; we would by some number, that is the number I am trying to get fixed in my mind, reduce the amount of carbon dioxide in the atmosphere.

Mr. SCHNEIDER. Yes, that is true, but it would be transient. If you could increase the size of the biosphere, you take some pulse of carbon dioxide out.

Mr. BROWN. All effects are transient.

Mr. Chairman, recognizing the time problem, I won't explore these questions any further.

Mr. GORE. If DOE cuts out the effort to narrow the uncertainties involved here, what chance is there that the research will be picked up elsewhere?

Mr. LAVE. Let me start on that briefly.

As you know all too well, there has been a lot of budget cutting for government agencies, particularly in nonessential areas such as research and development. It would be extremely difficult to find a pot of money outside of DOE to support this research.

Furthermore, it seems to me that if energy policy is being made within DOE, and this is an essential aspect of energy policy, then there are very good reasons to keep it there to make sure that

when DOE's decisionmakers are looking at the future of energy policy that they are getting relevant inputs from their own people.

Mr. GORE. This hasn't been put in any block grants to local communities or States?

Mr. LAVE. That is correct.

Mr. GORE. You haven't seen any interest on the part of civic clubs in picking up the research? I take it the answer is no, then.

Dr. Smagorinsky, is there any reason why elected policymakers in the Congress of this country should conclude that this whole thing has been blown wildly out of proportion and that it is just science fiction or someone's fantasy?

Mr. SMAGORINSKY. I would say that there is absolutely no basis for reacting that way.

Mr. GORE. No basis for reacting that way?

Mr. SMAGORINSKY. That is right.

Mr. GORE. It is true, is it not, that this began on the fringes of science to the extent that a very few individuals made the argument and the vast majority of scientists couldn't make themselves believe that it was real, and that over the last several years the hypothesis has gained adherents exponentially; that it now represents the mainstream view in the atmospheric sciences?

Mr. SMAGORINSKY. I believe you are right, sir, based on what we now know.

Mr. GORE. Moving up the pyramid, is it also true that the mainstream of science now agrees that the effects will include a big increase in the sea level? What about that? Take that one first.

Mr. SMAGORINSKY. Well, big is an "iffy" statement.

Mr. GORE. Depending on how close to the water you live?

Mr. SMAGORINSKY. Well, no, there is a physical reason. If you are only talking about a secular melting of sea ice, then I do not think "big" is warranted. If you are talking about something catastrophic, such as the dropping of the Antarctic ice shelf into the sea, this could give rise to a big change in sea-land, but such a possibility is highly speculative.

Mr. GORE. Dr. Schneider, what about that?

Mr. SCHNEIDER. I agree with Dr. Smagorinsky. You are very unlikely to change the sea level much by melting sea ice, any more than if the ice cube in your martini melts, it won't flow over the top, it is already floating. What counts is ice that is now on land.

The time scales for changing significantly most parts of landed ice are really hundreds to thousands of years. There is only the one exception, which is a major argument; that is the piece of the west Antarctic which has a shelf which is floating, the floating shelf is also pinned on some islands so it serves as a physical restraint to the ice back on the Antarctic.

The question is, if you warm up by 5 degrees or more, can you break up the shelf, not melt it, just break it up so you can get what they call a surge. There is a major debate among the glaciological community, several of whom feel it can, but it would take decades or longer to get a 5-to-8-meter sea level rise; others who feel the west Antarctic is in fact in a growth phase now, not likely to surge.

One of the chief problems is trying to figure out just what that ice sheet is doing. What bothers me is it may take us another two

decades before we begin to have an answer to that question. It is very expensive research; people don't even know how old the ice sheet is. So if you want to do science by consensus, you can say what is the probability it will occur? You can add up the number of glaciologists one way or another. You can find 20 percent who think it will surge, 50 percent aren't so sure, 20 percent think it won't for hundreds of years, etc.

You can do the other approach my colleague Robert Chen and I did, which is, supposing the surge happens physically, then what happens economically? What happens, you can calculate the fraction of land lost. You get numbers in the trillions of dollars and you are back into the discounting question. It is more likely to happen in 100 to 200 years than in 50, so how much is the trillion dollar cost worth to you now, if it occurs then; what about the transition? There are all sorts of secondary effects we don't include, as my economist colleague will tell me quickly. So that question is one of the more speculative questions.

I said regional questions are more difficult; that one is even more so because so little is known about the change of that ice sheet and so little evidence in the past that you have to start building theories and models, and that is just what the community does. And when you have an unverified theory—as someone from Missouri would say, "Show me" which is on the license plate—it is very hard to show them this is going to happen because you have to build a theory.

Unfortunately, the consequences of it, if it occurs, are very large. We are stuck trying to decide whether to hedge against this possibility without any way to verify, really.

Mr. GORE. Yes. The area of uncertainty associated with climatological shifts is less, is that correct?

Mr. SCHNEIDER. I would say certainly much less——

Mr. GORE. By an order of magnitude?

Mr. SCHNEIDER [continuing]. Than the ice sheet question. Yet the details of climatic changes are speculative.

You were earlier asking about what happens if the Grain Belt shifts. It was pointed out it is hard to shift farming because of the soils, and so forth.

An analogy to CO_2 may be one of the studies by Flohn which referred to a variety of pieces of evidence, including the climate in the late Paleocene 5 or 6 million years ago, when there was no Arctic Sea ice, but there was an Antarctic ice sheet. That was a fairly distant period.

Others, like my colleague William Kelogg, looked at 5,000 to 8,000 years ago. I mentioned the sand dunes drifting in western Nebraska. That was also a long average period compared to decades for CO_2 increases.

All the doubling experiments with carbon dioxide have been with equilibrium models; you increase carbon dioxide to a doubling, hold it fixed, run the model so that the climate reaches its average new condition. We are not having a doubling instantaneously occurring; there is this gradual transition. When you study that, one has to model the effects of the heat capacity of the ocean, how the waters mix. You can find this in one of the models that are run at Smagorinsky's laboratory and they are completely correct.

Suppose we had a complete doubling and held it for 100 years in a model. That result, no matter how reliable for the doubling, isn't necessarily the climate change you would get over the next 50 years of transition to the doubling. Things could be regionally very different during the transition period.

Right now we are adding oceans to the models to see what the transients are. So the certainty drops on a regional basis because what is important for planning, the transient evolution, is harder to do because you need to have deep oceans.

Mr. GORE. Do other countries have efforts like this one under way?

Mr. SMAGORINSKY. Yes, they do. There is in Britain, for example, the United Kingdom's Meteorological Office, and there are studies with simpler models being done in several other nations around the world, West Germany, for example.

Mr. SCHNEIDER. There is work in Australia.

Actually, no group that I know of has had—again I will praise DOE—the comprehensiveness of the DOE program, at least the one constituted as of a few months ago; it was really leading worldwide.

Mr. GORE. It was? What was?

Mr. SCHNEIDER. Well, that will remain to be seen. But clearly we were in the lead in the sense of taking a look across the efforts in CO_2 research. But, there are isolated, in some cases substantial, efforts of non-U.S. national groups.

Mr. GORE. Do you agree with Dr. Smagorinsky that there are no threshold levels at which an increased rate kicks in?

I think Mr. Scheuer mentioned it earlier.

Mr. SMAGORINSKY. May I clarify what I meant. When one deals with a doubling of CO_2, nothing abruptly happens during the course of it, and you can interpolate the present levels from the results of a doubling experiment.

On the other hand, there is one result now which shows that if you quadruple CO_2, indeed, you do traverse a threshold. That is, in the resulting equilibrium climate there is complete melting of the Arctic Sea ice during the summer. That is a threshold, something suddenly happens somewhere during the course of going from what the CO_2 level is now to 4 times.

Mr. GORE. Yes.

Mr. SMAGORINSKY. In that case it is a lot chancier to do an interpolation say to some intermediate situation.

Mr. GORE. You can't identify a permafrost threshold of the kind hypothesized by Professor Revelle?

Mr. SMAGORINSKY. Probably not nearly as demonstrative as a complete melting of the Arctic Sea ice in the summertime.

Mr. BROWN. Would the gentleman yield briefly?

Mr. GORE. Be glad to.

Mr. BROWN. Another type of what might be called a threshold, is there any evidence that you reach a point where the ocean uptake ceases or diminishes drastically because of saturation effects or something of that sort, so that the rate at which the carbon dioxide would increase would go up substantially as a result of the rapid decline in the uptake of the ocean?

Mr. SMAGORINSKY. There is no threshold I know of.

Mr. GORE. We will submit additional questions for the record in the interest of time.

Certainly we want to thank all of our witnesses here today. It has been most interesting. Thank you very much.

Mr. GORE. We will now go to our last panel, which consists of witnesses from the executive branch, led by Dr. N. Douglas Pewitt, Acting Director of the Office of Energy Research at the Department of Energy, accompanied by Dr. James Kane, Associate Director, Office of Basic Energy Science, and Mr. Frederick Koomanoff, Director, Carbon Dioxide Research Programs.

We will wait to hear Dr. Marcum and Mr. Belsky. I thought we were going to have everybody remaining in a panel but we are going to do it this way.

If our expert witnesses wish to stay around for this testimony, we may want to recall you and ask for some responses to what the executive branch witnesses have to say.

Welcome Dr. Pewitt and Mr. Koomanoff, and Dr. Kane.

I understand that you have a prepared statement, Dr. Pewitt. Without objection it will be put into the record in full at this point.

We invite you to proceed with the presentation of any or all of it as you see fit.

STATEMENTS OF N. DOUGLAS PEWITT, ACTING DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY; JAMES S. KANE, ASSOCIATE DIRECTOR, OFFICE OF BASIC ENERGY SCIENCE, AND FREDERICK KOOMAOFF, DIRECTOR, CARBON DIOXIDE RESEARCH PROGRAM

Mr. PEWITT. Thank you, Mr. Chairman. It is a pleasure to be here.

We submitted testimony obviously directed at the wrong subject. So I will just let that stand in the record and make a few comments reacting to what apparently seems to be the concern here.

Several months ago, I testified in defense of a Department of Energy carbon dioxide program in which the administration proposed to spend $14 million in 1982, up from $9.7 million in 1981. This request was the same as the previous administration's.

Despite the hallway gossip we have heard here today, the budget request of the administration has not changed. We intend to use the funds in 1982 in the way that the congressional budget request asked to use those funds. I know of no policy change in the Department. There have been some managerial changes that we have undertaken in order to more effectively manage the Department's funds.

That concludes my statement. I have next to me the acting head of the carbon dioxide program, Dr. Koomanoff. We will try to respond to any technical questions or speak in general to the policy. Also present today is Dr. Kane who is head of the basic energy sciences program.

Mr. GORE. Dr. Pewitt, we have heard there has been a cut in the direction of the program and in the research included in this program. Is that inaccurate?

Mr. PEWITT. Absolutely. In order to cut it would be necessary to reprogram. We have proposed no reprograming or changed our budget request to the Congress.

Mr. GORE. Fine, go ahead.

Mr. PEWITT. There are some changes being made in the management of the program. One of the changes is, we will not ask people for advice on how to put a program plan together and turn right around and feed them money that they helped formulate the program plan for. That is not the way to do the public business. We are not going to do that. We are not going to do social research on how Congress makes their decisions under the rubric of the carbon dioxide program. However, the program that we are going to execute is the program set forth in our congressional budget request in both January and in March.

Mr. GORE. Let me just ask you, in fiscal year 1982 in the area of effects of climate change and carbon dioxide increase on the environment, you still plan to spend $3.324 million?

Mr. PEWITT. That is not part of our congressional budget request. We intend to spend an appropriate amount of money on those environment effects. I think we have already let a contract this year for $700,000 with the Department of Agriculture to start looking at some of those effects.

Mr. GORE. Let me clarify this in my own mind. This is not hallway gossip, this is the National Climate Program Office document that says "Prepared by the United States Department of Energy Assistant Secretary for Environment." And it says, "In the program summary, effects of climate change and carbon dioxide increase on the environment, $3.324 million."

Mr. PEWITT. That is not part of the Department's budget request.

Mr. GORE. That is what the Department says is going to be spent on that area of carbon dioxide assessment effort and my question to you is, has that been reduced?

Mr. PEWITT. We are addressing that now. We are presently assessing this program and no commitment has been made to a specific level of funding. As yet, I do not know what the right level of funding is. Our congressional budget request does not specify those specific amounts.

Mr. GORE. The national climate program report did, the Department of Energy publication.

Mr. PEWITT. And the publication date on that was——

Mr. GORE. This is January of 1981.

Mr. PEWITT. Yes, sir, I am aware of that. However, that is not a departmental budget request. I have never seen the document and that is not what I testified in defense of.

Mr. GORE. But that was an accurate reflection of what the Department's program was planning to spend in this category?

Mr. PEWITT. Some months ago, that is correct.

Mr. GORE. And that is now being reduced, isn't it?

Mr. PEWITT. That is being reviewed; not reduced.

Mr. GORE. It may be increased?

Mr. PEWITT. I do not know. The director of the program, in whom I have absolute confidence, is looking into it. He and I have been in very close touch and while we are addressing the issue seriously, we do not know as yet what the right amount is to execute a program.

Mr. GORE. Let me go to the next item, social, political and economic costs and/or benefits of the global environment change.

That figure is $960,000. Do you still plan to spend that amount——

Mr. PEWITT. We plan to review that amount too and see if it is sensible.

Mr. GORE. Maybe the staff of Mr. Scheuer's subcommittee picked up information informally, what you refer to as hallway gossip. But that source of information indicated this part of the program was in some jeopardy. Is that inaccurate?

Mr. PEWITT. When I found out that, in the social research part of this, there was research aimed at things like how Congress makes decisions, I was less than happy that we would propose, in the rubric of carbon dioxide assessment, to spend the taxpayers' money on that sort of social research. That is appropriate at some point perhaps but not appropriate as part of the carbon dioxide program.

Mr. GORE. You may be right about that.

What do you consider useful social and economic analyses in this area?

Mr. PEWITT. I have a program director currently looking at that, and he is going to come back to me with a proposal. We are planning to address the issues that, if addressed, can come up with something useful. We are not going to fund research under the rubric of carbon dioxide that possibly can't find a home someplace else.

Mr. SCHEUER. Will my colleague yield?

Mr. GORE. Sure.

Mr. SCHEUER. I am pleased to hear your attitude. It is perfectly obvious we don't want that kind of research either. However, we are concerned about the social, economic, and political implications of the destabilization that would be caused, looking into the future generation or two, by the kind of phenomena we have heard about. When we are told that we can look forward to enough change in the level of the ocean to require 40 percent of the population of Florida to be uprooted and relocated we are looking at massive social, economic, and political change.

There are many places in the world, particularly in the developing countries, where the cost of relocating populations that are located near oceans would be painful, cruel, and nearly impossible. Those kind of dislocations in many parts of the world can't be faced and they have potentially devastating economic and social and political implications. It is this that we think we ought to be measuring, because the loss is not just crop loss, but vast human destabilization, and that goes far beyond the cost of crops or forest lands or grazing lands.

We are talking about major dislocations that have not only national but regional and international implications. It seems to me it is that general area that must be addressed and for which a research program should be designed. I think we are knowledgeable enough to look at the program as you have developed it, consult with experts, and come back with some intelligent reactions to that program. I hope and expect that we will have a chance to do it. Can you tell us what time constraints have imposed on your research people?

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Mr. PEWITT. Well, we have just made, I think, the management changes that are necessary to have a responsible, reasonable, cost-effective asesssment of the carbon dioxide issue.

Mr. SCHEUER. You just told us that you had asked your people to come to you with a research program?

Mr. PEWITT. That is right.

Mr. SCHEUER. When will you have that?

Mr. PEWITT. I haven't given them a definite deadline. We are proceeding on the old plan and taking a look at marginal areas. In 1982, we will have a program. We have to start putting together our 1982 spending plans very soon. I am going to review those before the middle of the month.

Mr. SCHEUER. Before the middle of what month?

Mr. PEWITT. August.

Mr. SCHEUER. Would you be able to come back to us after Labor Day and discuss your research program and the role that socioeconomic and political analyses play in that?

Mr. PEWITT. We have to put things together. There are certain procurements that are going to be scheduled for later in the year. It will probably be late September before we finish those.

Mr. SCHEUER. That is entirely satisfactory. We will call you around mid-September and set up a date. We would be very interested in looking over your research design at that point.

Mr. PEWITT. I would be very pleased to do that.

Mr. GORE. The amount you plan to spend in this area is what again?

Mr. PEWITT. $14 million in 1982 appropriations. The authorization committees were very generous to us in this area, even though it was a significant increase. The Appropriations Committee of the House so far supported that. If the Lord and the Senate be willing, we will spend $14 million in 1982 on this program.

Mr. SCHEUER. Will my colleague yield just briefly?

Mr. GORE. Yes.

Mr. SCHEUER. We all know that this is a time of real constraints on funding. I commend the administration for picking out a few areas of critical need and expanding research. They have done it for acid rain and they have done it for research on cross-disciplinary valuations of disposal of sludge. Furthermore, I commend the fact that they have given you an adequate research budget for a systematic analysis of this major problem. When the administration makes a very thoughtful and constructive decision in this whole area of science and technology research, they are entitled to a little credit for doing that.

Mr. GORE. What was your request for fiscal year 1982?

Mr. PEWITT. I didn't make the request. The responsibility for program management has changed with the administration.

Mr. GORE. With the new administration?

Mr. PEWITT. Yes.

Mr. GORE. Did you reduce the request when the new administration came in?

Mr. PEWITT. Absolutely not. If I can take just a second: There was an Assistant Secretary for Environment who had responsibility for the compliance with NEPA, the overview of the safety activities of the Department, and sort of a mish-mash of activities in addition

to a research program. With the realignment of the Department, the research program came into the Office of Energy Research in April. With that research program, I inherited a budget request. I was part of the process of reviewing the total DOE budget for 1982 and its revisions from the January budget. There was uniform consensus that the carbon dioxide program deserves support.

At this time, we are going through the formulation of the 1983 budget, and, as yet, we don't know what is going to happen with that. Nevertheless, our intent is to execute the program that we presented to Mr. Scheuer's committee back in March.

Mr. GORE. I have the fiscal year 1982 request, $16.698 million. What is that figure?

Mr. PEWITT. I do not recognize that figure.

Mr. GORE. That was presented to Mr. Scheuer's subcommittee.

Mr. PEWITT. Included in the $16 million was the high altitude and climate research element not related to the carbon dioxide effort. It is air sampling and general atmospheric research. The $14 million was the carbon dioxide portion.

Mr. GORE. Well, maybe I owe you an apology, Doctor.

Mr. PEWITT. No.

Mr. GORE. I was under the impression that you all were in the process of cutting this program. Perhaps that originated with the American Association for the Advancement of Science proposal being cut. Is that likely how that came about?

Mr. PEWITT. The American Association for Advancement of Science proposal has been submitted to us and is under review. We haven't funded it. I am looking very carefully at associations that propose to us elements of a program plan and then present us with a funding request immediately after that. There is a question of public policy—of how we do our business as a government.

Mr. GORE. I hope that the Department will not cut the research in this area and will include an appropriate amount for analysis of the economic and social effects of this problem, and will consider the possibility in reviewing the fiscal year 1983 request of doing everything possible to accelerate the effort to narrow these areas of uncertainty.

I take it that—let me ask you, do you share the sense of urgency that I feel about getting a firmer grip on whether or not this problem is in fact occurring?

Mr. PEWITT. No.

Mr. GORE. Tell me why?

Mr. PEWITT. I think that in running a scientific research program, we have a responsibility to the Congress and the American people to act in a fashion that is not alarmist. We have been down this road in similar areas before; for example, in aerosols and in the SST's disturbing of the atmosphere. It clearly is the prerogative of the Congress and policymakers to set a higher priority than the scientific programs can produce research results. There is a natural approach to scientific research that probably would not justify much of the more alarming carbon dioxide statements. I absolutely refuse as an official in a responsible position to engage in the type of alarmism for the American public that I have seen in these areas time and time again, and I do not think that I can responsibly encourage that sort of alarmism.

Mr. GORE. I think that is very helpful. And I do not think it is good to be alarmist about these matters either. But I do not believe that the analogy to the aerosol problem and the SST dispute squares with the kind of data reflected in that middle chart. That has been gathered over the past 23 years, and it reflects a consistent pattern, quite unlike the skimpy evidence upon which the SST and aerosol debate was based.

This is a rather impressive body of data that continues to accrete. Doesn't that lead you to look at it in a different light?

Mr. PEWITT. I have seen that chart too, and I am very familiar with all the bumps in it.

Mr. GORE. Yes.

Mr. PEWITT. I am not an atmospheric scientist as one of the earlier witnesses alluded; I am a high energy physicist, a particle physicist. I understand false correlations; until one understands fundamental mechanisms of how things happen, they can be trapped into false correlations. Twenty-three years is not exactly a significant timeframe in the weather.

Mr. GORE. We have it going back to 1958 with reliability but the same pattern goes all the way back to 1880, and you can see fluctuations for the Great Depression, for two world wars.

Mr. PEWITT. To counter that, you have an increase in carbon dioxide since the forties, and the mean temperature has been decreasing slightly. You have several different effects going on here at the same time. It is a very difficult system to understand; this is a very complex physical system.

Mr. GORE. Absolutely.

Mr. PEWITT. Understanding it is not easy. We have some bright people advising us on this program. We don't, as Federal officials, try to put our scientific judgment against others. We try to reach and get reasonable advice, and use peer review and advisory bodies to tell us how to proceed in this area. One should make sure that their advice is solidly based scientific advice.

Roger Revelle, the distinguished scientist that you had up here before, is part of that advisory body. You can't have bureaucrats dictating science, but at the same time you can't have scientists using alarmism in order to justify bigger research budgets. That is irresponsible, too. We are just trying to approach this issue reasonably.

Nobody predicts anything to happen in less than 50 years. It is important not to waste the next decade, but it is also important not to jump off and get the American public concerned, stop synfuels, stop everything in the world, on the basis of misinformation.

We intend to pull together information in the timeframe we are talking about. We will have a reliable basis to know what is reasonable to anticipate. You never know precisely in this business; all you do is narrow the bounds of uncertainty. We will have narrowed the bounds of uncertainty very considerably in 2 or 3 more years in this program.

Mr. GORE. I certainly agree that the areas of uncertainty are too large now to justify a halt to the synfuels program or a dramatic move away from fossil fuels right away.

I do think that the areas of uncertainty are narrowing and have been narrowing consistently over the last several years to the point

that the issue now is agreed upon by the mainstream of the atmospheric sciences; that they agree that it has acquired a new percentage of certainty, if I can use that rather awkward phrase.

I think that ought to lead us to reevaluate the importance of building options for our energy future, and should lead us to greatly accelerate the effort to narrow the remaining areas of uncertainty. And while we ought to avoid alarmism, we also ought to avoid a head-in-the-sand attitude at the same time.

Let me ask Dr. Koomanoff: You are the director of the carbon dioxide research program, is that correct?

Mr. KOOMANOFF. That is correct, sir.

Mr. GORE. Do you agree with the previous panel that this is a problem of growing urgency, if not one that is firmly established as a definite effect that is going to occur?

Mr. KOOMANOFF. I think that the carbon dioxide concern is a very important one and we must get some good scientific answers to this important issue. I have been in charge of the carbon dioxide program for 3 weeks; however, I have had previous experience in climatic research. There are many questions and much uncertainty that must be resolved. One question deals with how good the climatic models are; another with our understanding of the carbon cycle as to the sources, sinks, and fluxes of carbon dioxide. Has the world's deforestation been as severe as we think it has been? We do not have hard data on some of those issues.

We don't know precisely how the oceans work. We know there are time lags in how much carbon dioxide the oceans absorb—it may be 10 to 20 years. Accordingly, some of the correlations on a short 23-year time period for which we have good data as to atmospheric carbon dioxide and fossil fuel usage must be carefully reviewed. From an overall standpoint, carbon dioxide has increased. This is caused not only by fossil fuels, but by deforestation also.

My job right now is to develop a sound, scientific program to obtain information and specify what is known, what is unknown, and what is uncertain, so that you in the policymaking area can make logical decisions.

We will take necessary environmental impact areas into consideration. At first, we must learn about first-order effects: the first order effect of carbon dioxide on climate and the effect of carbon dioxide on vegetation.

Our models are becoming very much better A consensus in the scientific community is growing as to the accuracy of models. However, much improvement in our computer models is required. Just 2 weeks ago, I had a presentation where a new model is now adding 47 different vegetation classes into the model. These data are required because different classes of vegetation affect carbon dioxide and oxygen usage in different ways.

We are trying to move ahead in a logical, prudent, and as rapid a way as possible. So yes, the carbon dioxide concern is an extremely important one; we have to get answers because it is important to all of us. But to try to make a conclusion at this point with our lack of knowledge and the great uncertainties that exist and jump into the future is a very dangerous thing to do. We can lead ourselves down paths and try to make decisions before we have the data required to make scientifically based, sound decisions.

Mr. GORE. Let me ask you a question——

Mr. SCHEUER. May I ask one?

Mr. GORE. Sure.

Mr. SCHEUER. How soon do you think you will have reliable data upon which you can base energy policy decisions?

We are engaged in a massive movement in this country away from Persian Gulf oil. We have seen the poisonous effects that our dependency on Persian Gulf oil has had on our foreign policy as well as on our economy. This move away from Persian Gulf oil includes a tremendous national priority on synfuels, coal conversion, nuclear progress, and more environmentally benign means of producing energy such as wind, tidal, solar, biomass, and the like.

If we face a very real problem 20, or 30 years from now, that might effect where we are going to spend hundreds of billions of dollars on development of synfuels and coal conversion programs. Within the reasonably short-term future, I think we are going to be making massive capital investments in those programs.

One of the factors involved in making cost-benefit calculations would certainly be the short-term and long-term risks to the atmosphere that would be involved in going massively toward synfuels and coal conversion. How soon are you going to have a data base sufficiently reliable to put some of these factors into our public policymaking machinery on development of new sources of energy?

Mr. PEWITT. Well, I think we have an adequate data base now with regard to our synfuels. The United States has about 26 percent of the fossil use of the globe. So, whatever we do only changes the time frame for whatever is going to happen, and not by a significant amount.

The synfuels industry and the last administration testified about a rather ambitious synfuels program which is probably not realistic. It was a target, but even that amount of synfuels over the next 20 or 30 years would not make any significant amount of difference in the carbon dioxide in the whole atmosphere.

On the chart you have, you are seeing a small wiggle of a few percent on top of a very large base. That chart is very deceptive in that way.

It is a clever piece of chartology, in that it is intellectually accurate, but can be subject to being read the wrong way.

Mr. GORE. If you look at a longer range chart, going back to 1880, you see virtually the same thing, and, in fact, if you take a longer range perspective, you can construct a chart that looks even more extreme in terms of its illustration of the correlation between fossil fuel burning and CO_2 buildup.

Have you seen the longer range chart to which I refer?

Mr. PEWITT. I would like to have it credibly reviewed scientifically, get a sound projection of what the details are based on and determine what carbon dioxide has done in previous history. I wish this type of review existed. We are trying very hard to sort it out.

With regard to projections, I can apply my percent growth and others can apply theirs. The important thing in the question you ask me is, do I share your sense of urgency. Nothing we are going to do in the synfuels area over the next 30 years—outside of just totally foregoing synfuels, for which I don't think there is a reasonable basis, and your expert panel didn't indicate such—is going to

make a whole lot of difference in the amount of carbon dioxide buildup.

Mr. GORE. I have been a supporter of the synfuels program, and I think, for other reasons, it makes sense for us to develop the capacity to change our domestic resources into a form that can be used, but the entire fossil fuel consumption by our country and others is called into question to a minor degree by this effect. If it is real, then fossil fuel burning generally is called into question.

Would you agree?

Mr. PEWITT. If, in fact, there are some of the effects that are hypothesized for doubling, tripling, quadrupling, whatever value you want on our climate, it is called into question. I think it is very important to understand the climate response to carbon dioxide in the atmosphere, and we are trying very hard to do that.

I don't share your sense of urgency that we have to do it immediately on a crash basis. To begin with, I think you will get spurious results, and you won't get scientific information. There is no basis—and I don't think there is anyone who proposes there is a basis—on which to make any public policy decisions at present.

We will have narrowed that uncertainty considerably over the next 3 or 4 years, and we will be in a position to see if there is reason at that time. There are many people who have tried to use this issue to try to kill the synfuels program, and now there are pronuclear people who say we should have an all-nuclear future. That is not good public policy, either.

It does call into question how much reliance for how long. There is no doubt about that, but it is a question of what is the urgency, and I just don't think it is a problem that 6 months, 12 months, 18 months, 36 months from now is going to endanger the Republic if we don't have a crash program in this area.

Mr. GORE. Let me ask you a hypothetical question. If the areas of uncertainty were significantly narrowed to the point where you believe that the effect was real, would you then recommend a strategy of adapting to the consequences, or would you recommend a strategy of attempting to negotiate with other nations a change in the pattern of fossil fuel use in the entire world?

Mr. PEWITT. I would probably endorse doing them all, with the hopes that one or the other would succeed. You would probably not be able to succeed totally in anything; but we don't know that, and it wouldn't even be a matter of urgency then, I don't think. Realistically you wouldn't be able to get significant social changes made on the basis of scientific information, anyway, until the event became real to people. That is a basic problem with this. More enlightened public leaders would try to shape public opinion. Nevertheless, it would take a long time before you could get the dramatic social changes accepted that would be required.

Mr. GORE. We have a vote on social security on the floor, and we are just about finished with this panel. We will recess for 10 minutes and then come back.

[Recess.]

Mr. GORE. The subcommittee will come back to order.

Dr. Pewitt, the AAAS program has not yet been terminated; is that correct?

Mr. PEWITT. I don't know.

Mr. KOOMANOFF. The contract has not been renewed.

Mr. GORE. Has the AAAS program been canceled?

Mr. KOOMANOFF. The proposal is under consideration.

Mr. GORE. So it has not been renewed, and it may not be renewed, but the decision is yet to be made?

Mr. KOOMANOFF. That is correct, sir.

Mr. PEWITT. If I might interject now, I have very serious concerns, and the department has been taken to task by the Congress on numerous occasions for this closed loop funding. If I suggest the department adopt the proposal, then we are putting money back to the same people who suggested we do the program.

I have a responsibility to see that this gets very close scrutiny so we can't be taken to task again.

Mr. GORE. I think that is right, and I agree with you. On the other hand, the next question is, if it is terminated, how do you plan to develop a comprehensive assessment without it?

Mr. KOOMANOFF. First of all, sir, to develop a comprehensive assessment and to carry out a comprehensive assessment is the responsibility of the Department of Energy. I cannot delegate my responsibilities and my authorities to any group, the AAAS or any other contractor, or other Federal agency. I must hold that responsibility.

We will develop within the Department of Energy as part of the Carbon Dioxide Research Division, an integrated assessment of the carbon dioxide issue. It will be documented; it will be put out for peer review nationally and internationally.

We have been working with OSTP and with NSF to have the National Academy of Sciences do work in this area. I am hopeful that they will be able to give us an oversight so that they can look at what we are doing, see if there are any errors of omission and commission in what we are planning, and what we are actually contracting, to give us advice as to priorities and scope of different issues; but the final decision and conduct of an assessment of this type must be done by the Department. I cannot delegate this, and I will not, sir.

Mr. GORE. If the AAAS program is terminated, you would plan to complete those parts of the comprehensive assessment inhouse?

Mr. KOOMANOFF. No, we would contract it out to different groups.

Mr. GORE. To someone else?

Mr. KOOMANOFF. To universities, to laboratories; and we would put out RFPs for help; yes, sir.

Mr. GORE. Now, does DOE plan to continue as the lead agency in CO_2 research?

Mr. KOOMANOFF. Yes, sir.

Mr. GORE. Do you plan to consult with the other agencies involved about changes in direction?

Mr. KOOMANOFF. Yes, sir. There is a committee set up under the national climate program office on CO_2 that will be meeting probably in September, and at that time we will be discussing the plans because, after all, we have stated that in October we would be glad to come back and discuss our plans with this committee, or committees. It would be very improper if we did not discuss our plans with those people of sister Government agencies.

Mr. GORE. Who is the head of that interagency committee?

Mr. KOOMANOFF. That subcommittee is chaired by the Department of Energy.

Mr. GORE. Is there an individual who is the head of the interagency committee?

Mr. KOOMANOFF. Yes, I will be that individual. I will chair that subcommittee.

Mr. GORE. You took David Slade's place, did you?

Mr. KOOMANOFF. Yes, sir.

Mr. GORE. Mr. Chairman, those are all the questions I have of this panel. I wanted to get the reaction of our expert witnesses. Is it appropriate to do that now while they are present?

Mr. SCHEUER. By all means.

Mr. GORE. I wonder if Dr. Schneider could come and join the other witnesses here for a couple of very brief questions. I won't ask everybody to come back up unless they want to volunteer.

Dr. Schneider, Dr. Pewitt and I had an interchange about how the Government, the legislative and executive branches, ought to perceive this problem. It is very difficult. I began my opening statement by saying it is difficult to come to grips with this problem because you have such large areas of uncertainty.

On the other hand, the consequences of the problem, as it is determined to be a real problem, are so enormous that it is not too early now to begin thinking about a response so we can eliminate the areas of uncertainty.

I am sure you picked up, as I did, the fact that Dr. Pewitt is much more skeptical about this matter than the panel of expert witnesses that preceded this panel. If I am misstating your position, you jump in at any point, Dr. Pewitt.

If our country and our society are to have a mature and intelligent response to this problem, then the tone of that response is critical. Dr. Pewitt cautions us again against alarmism. I would agree.

I used the word "urgency" hoping it would not connote an alarmist tone. What do you think the proper tone of our response should be?

Mr. SCHNEIDER. Whether one is an alarmist or considers the CO_2 problem urgent isn't based on any scientific information. It is a value judgment. It depends upon how you personally fear potential risks versus how you personally fear the costs of mitigating them, versus your own political philosophy about whether individuals should be free to do what they want, or whether we have collective responsibility.

The whole question of urgency or alarmism really is not something that I think a group of experts can define. All we can do, as experts, is try to list what are the possibilities and, in particular, what the uncertainties are. Given that, I am happy to give you my values, which are that I think the CO_2 problem is only urgent in the sense that a lot of its solutions are also related to solutions to other pressing issues, as I said earlier, such as developing crop strains, maintaining flexible energy supply options, changing soil horizons.

To me, these are urgent for other reasons than CO_2, and what CO_2 does is contribute to the need to maintain open options. In

that sense, it is urgent. In the sense the Republic would fall in 10 years, I certainly agree it wouldn't, from the CO_2 problem.

We are talking about incremental change, but as CO_2 is so akin to other problems; and as it is long lasting and takes a long time to make social change; and as it takes a good 20 years before we will have consensus on many of the issues—and 20 years is a timeframe when present models suggest we get these detectable signals—we have to commit posterity to adapt to some level of CO_2. So, there is urgency in the sense we are already creating the commitment to some environmental change.

I do not believe that change will necessarily be catastrophic, although the issue of catastrophe is almost irrelevant. The issue is, if we have done something, and if we can know who did it, there is the question of equity as to who should be responsible or how we can minimize the damages so that it is not a catastrophe.

It is like many other pollution issues. I have a sense of urgency in the view that we need to consider now those actions which increase our options. In that sense, it is urgent. In the sense it will be an urgent catastrophe which will eliminate all life, that kind of statement is absolutely unwarranted.

Mr. GORE. Thank you very much.

Did you want to respond, Dr. Pewitt?

Mr. PEWITT. No. His is a fair statement.

Mr. SCHEUER. Looking at this red book, which is the Carter administration research issues——

Mr. GORE. We had some discussion about that, Mr. Chairman.

Mr. SCHEUER. I understand that, and I understand we got the signal this is not their program; they are going to produce their own program.

You apparently have a budget of about $14 million for your CO_2 research.

Mr. PEWITT. In 1982; yes, sir.

Mr. SCHEUER. You have six categories here. Can you tell us, as a percentage of your $14 million, how each of these six categories would come out?

Mr. PEWITT. I can't tell you percentage, but the major emphasis—and I have this in my testimony—is going to be on the carbon cycle, locking up what is doable scientifically in a rather rapid fashion. I think we can narrow the bounds of uncertainty quickly in that area. Where you have certainty, one should move ahead.

Climate effects are a tough problem. We have the benefit in the climate effects program of a massive expenditure in NOAA. We get a lot of mileage out of a little bit of money there. We are going to continue this effort very seriously.

We are looking hard at the environmental impact. There is some question of what carbon dioxide will do to humanity. That will receive emphasis.

The economic impact will probably be somewhat less. We are going to take a careful look to make sure we are not funding social science research to find out how Congressmen make their decisions. I think we can ask you and get that information free.

Mr. SCHEUER. Absolutely. We would be glad to meet with you anytime. However, the social, political, and economic costs, as well as how we factor these costs into our long-term energy policy

decisionmaking, are factors you undoubtedly have deduced are of real concern to the members of this committee. We will look with great interest on how that portion of the budget of less than $1 million for these 3 fiscal years fares under you.

Mr. PEWITT. If there is credible scientific research in this area that will stand up to review, we will do an appropriate amount of it.

Mr. SCHEUER. Dr. Pewitt, you have used expressions like "navel-staring" and "alarmism" quite freely throughout your testimony. Do you consider that the panel which preceded you is engaging in navel-staring and alarmism?

Mr. PEWITT. I was very impressed with the panel when they testified in their area of expertise. Outside their particular area of expertise, I don't have an opinion on their views, because it also is not my area of expertise.

I think the technical experts have the responsibility to stay in their area of technical expertise, when they are testifying as experts. When they are testifying as a member of the public and not an expert, then I think they should clearly declare they are not testifying as experts. We have seen that go on today.

Mr. SCHEUER. You didn't really answer my question.

Mr. GORE. In what areas did you identify a departure from expertise?

Mr. PEWITT. I think we have some remarkably competent physical scientists that are proposing social science research. I would propose that we ask responsible social scientists to address those. You had one, the gentleman up here, and I agreed with everything he said, except the fact that the Department was decimating our research program, where I think he was misled on his facts.

Mr. SCHEUER. He may have been listening to some of this gossip we have heard, too, but it is real. It is a perception that is real, and that you must understand exists.

Mr. PEWITT. I understand that.

Mr. SCHEUER. I couldn't agree with you more—it would be worthwhile to get social science research experts involved in this venture.

Dr. Schneider, what do you perceive to be the benefit and the value of the level of social science research that you would consider adequate and not alarmism?

Mr. SCHNEIDER. Well, I don't quite know what that means.

Mr. SCHEUER. I am not sure I do, either. We didn't get a clear answer from Dr. Pewitt, I might add.

Mr. SCHNEIDER. I am certainly aware of the problems that many social scientists have, and though I am not formally a social scientist, I have been affiliated with many social science groups—not just the AAAS effort, but the social science research council, and other such things, and there is often a tendency among some social scientists to "navel-stare"—whatever that means—or to try to even suggest one should research how Congress thinks.

Indeed, there were one or two lines somewhere in the panel which I cochaired with Elise Boulding, who is a sociologist, by the way, and which was made up of eight other members, all of whom were social scientists and historians, political scientists, social psychologists, and so forth, who did the work; and that suggestion on

Congress, while it was in there, was only one of the many questions, and it was under the whole subject of perception.

How people perceive warnings is not a trivial aspect of how people will respond to CO_2. But despite that, no recommendation came from that panel or from the phase II effort of the AAAS/DOE, also, to suggest that one spend significant or in fact any amount of money on that. The primary emphasis was on distilling from this whole large range of social issues a few tractable ones, and what was considered the highest priority tractable one was the integrated scenario analysis, which certainly would not have included surveys of Congressmen on how they think.

We would agree that should be a low priority issue. We would have no disagreement at all.

I think it is somewhat incorrect to say there was very little social science input in that recommendation simply because what the effort in phase II and phase I of the DOE's assessment has been, was to pull together social scientists from so many disciplines, many of them with hairbrained ideas, and distill out from literally hundreds of people, of which about 50 or 60 were social scientists, exactly what their thinking was.

Now, I think that it is not alarmist at all to analyze alternative scenarios for energy system development, for CO_2 impacts, and so forth, to find out in fact what matters. It is not just our idea as seen in my prepared testimony.

On another topic, I certainly agree with Dr. Pewitt that there is a conflict-of-interest question dealing with the fact that some of the AAAS people who were proposing the scenario research, who proposed this was important, are also writing proposals to do the work. In fact, this was quite clear to us when we were doing it, and we were nervous about it, and one of the remarks Dave Slade made when we brought this up was, "That is true, but you guys are not going to be the ones who are the peers to evaluate the value of the proposal. We will go for very heavy outside comments to make sure whatever you propose will work."

I think with that kind of external review, and I should think it would be even more heavily reviewed than perhaps normal because of the potential conflict of interest, one could eliminate that danger.

Mr. GORE. Dr. Schneider, within your area of expertise, do you agree with Dr. Pewitt that this chart is misleading or has the potential to mislead?

Dr. SCHNEIDER. Again, I have trouble knowing what that means. It depends on what we are asking of the chart. The chart by itself lists the fact how much CO_2 has changed. If you want to infer from this there will be so much in the future, then the chart can be misleading unless you state what the caveats and assumptions are upon which future CO_2 will increase.

Mr. GORE. Dr. Pewitt, I don't want to put words in your mouth, but I got the impression you were saying the significance of the chart should be substantially discounted.

Mr. PEWITT. No. What I said is that that is chartology. It is intellectually just exactly correct. It displays 315 going to 336, but it appears to be going from zero to very large amounts.

Mr. GORE. It is clearly labeled 316 to——

Mr. PEWITT. That is correct, and a person very careful in their review of this chart will see that that is true. That is the reason why I said it was intellectually correct. I mean, it is objectively a statement of fact that that is true.

The impression it leaves on some people is quite a different impression. I have always had trouble with playing chartology. It appears to be going from nothing to a vast amount, and that is a fact. We have a lawyer here who is nodding in agreement—it is true.

Mr. GORE. I will include in the record at this point a chart showing the trend from 1880 until the present time, which gives not only—well, which gives an impression that exactly corresponds to the impression which you are evidently worried about being misconveyed by this chart, and I would ask the staff to provide this chart to you and ask you whether or not you agree.

[The information follows:]

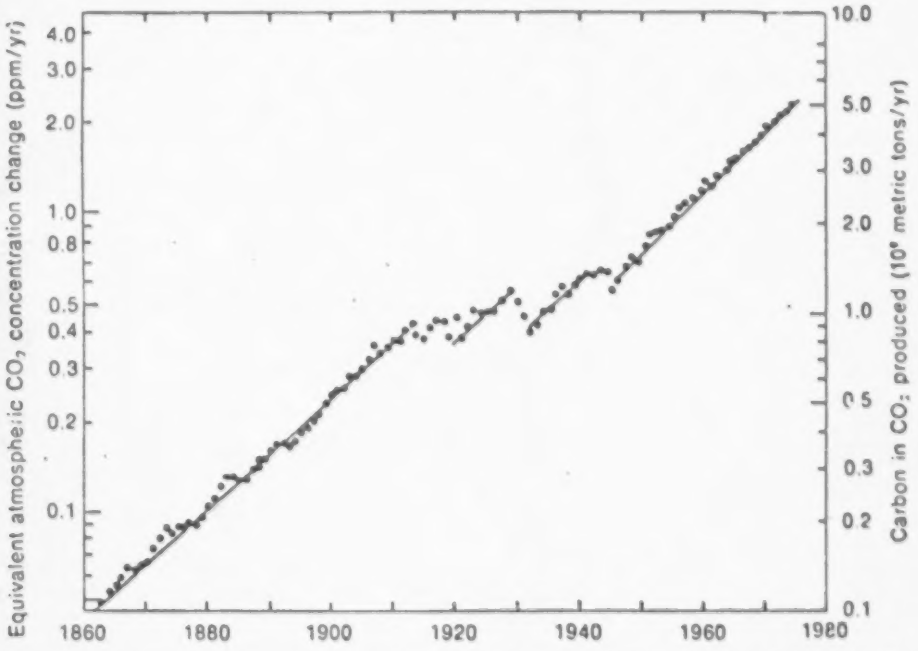

Figure 1. The annual world production of CO_2 from fossil fuels (plus a small amount from cement manufacture) is plotted since the beginning of the industrial revolution. Except for brief interruptions during the two world wars and the great depression, the release of fossil carbon has increased at a rate of 4.3% per year. (1860-1949 data from Keeling 1973a; later data from Rotty 1976.)

Mr. GORE. You will note the dramatic drop during the Great Depression, the drop during the two World Wars, and the rapid increase following the period of industrialization following World War II.

Mr. PEWITT. I am sorry, but the two charts are not comparable. The chart your staff has handed me is the annual world production of carbon dioxide, not the carbon dioxide in the atmosphere in parts per million. They are in the same chart, and they don't propose to do the same thing. I don't understand. If I look at this, and I can play chartology, there is a very steep rise from 1950 to

1980 in the use of fossil fuels—much steeper than the rise there. This is the problem with chartology; the charts are not the same.

Mr. GORE. Mr. Schneider?

Mr. SCHNEIDER. One has to make an assumption as to what the so-called airborne fraction is, what fraction of CO_2 which is burned remains airborne. During the 22-year period the chart exists—the chart on the wall—the airborne fraction has been roughly 50 percent. So if one makes that assumption, Mr. Gore's chart would be an accurate chart of CO_2 if you also knew what happened to the biosphere. It is clear there are some difficulties.

On the other hand, the point you are trying to make is that one could be misled. This sort of uncertainty cuts two ways: You can be misled to think the chart is overdramatic. You can also be misled to think it is underdramatic, because, if you plot it, based upon modeling efforts, the CO_2 increases from those models, based upon projections in the future, do indeed look very much like this (Mr. Gore's) chart, though the numbers are different, and you see the chart on the wall as a piece of an exponential growing, and, in fact, the rate of growth was much less steep before 1958 and becomes much more steep after 1980.

Again, there are assumptions in that, and they are not verified, and that is why we have a research program, but, again, a chart is a neutral thing. It is the question you ask that determines whether or not you are under- or over-impressed with it.

Mr. SCHEUER. I want to thank all the witnesses for your candid and helpful answers to our questions. We look forward with great anticipation to meeting with you in October and getting your thoughts on the question of the role that social, political, and economic costs/benefits will play in the total energy research calculus. Furthermore, we are interested in how we can put those implications of atmospheric change into our energy development decisionmaking process.

Mr. GORE. Mr. Chairman, may I also say for the record that I am impressed that the tendency to cut every single aspect of the budget at the Department of Energy was forestalled in this case, contrary to the impressions that I had prior to the hearing, and that I think that is an encouraging comment on the quality of analysis that Dr. Pewitt has brought to this particular problem, in spite of the different assessment of how serious the problem is. Evidently he agrees that the country needs to continue an aggressive effort to narrow the range of uncertainties involved. I appreciate that.

Mr. PEWITT. Thank you for the opportunity to clarify the Department's position.

Mr. SCHEUER. We appreciate it. We look forward to meeting with you in October. Thank you very much.

[The prepared statement of Mr. Pewitt follows:]

STATEMENT OF N. DOUGLAS PEWITT
ACTING DIRECTOR OF ENERGY RESEARCH
DEPARTMENT OF ENERGY
BEFORE THE
NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT SUBCOMMITTEE
AND THE
INVESTIGATIONS AND OVERSIGHT SUBCOMMITTEE
HOUSE SCIENCE AND TECHNOLOGY COMMITTEE
JULY 31, 1981

Mr. Chairman and Members of the Subcommittees:

I am pleased to appear before you to discuss the Department of Energy's carbon dioxide (CO_2) research program and the role it plays in the national CO_2 program. Before I turn to the Department of Energy (DOE) program, let me first comment on the significance of the CO_2 issue and the role various federal agencies play in the national program.

Carbon dioxide (CO_2) is a small but climatically important component of the earth's atmosphere. In recent decades the concentration of CO_2 in the atmosphere has increased at a rate nearly parallel to increased global use of fossil fuels. This increase is equivalent to about one half the CO_2 released in fossil fuel combustion, with the equivalent of the other half being absorbed by the oceans and biosphere.

There are a number of physical processes that can warm and cool the earth's lower atmosphere. Atmospheric CO_2 can warm the lower atmosphere by absorbing heat radiation from the earth's surface, thus preventing it from dissipating into space. As the concentration of CO_2 in the atmosphere increases, more of the earth's radiation is contained. For many years atmospheric physicists have been concerned that increasing amounts of CO_2 in the atmosphere would enhance the "greenhouse effect," which would result in warming of the lower

atmosphere. This, in turn, would cause changes in patterns of precipitation, evaporation and wind circulation. In the last decade, physically-based, mathematical simulations of the global atmosphere have tended to give added emphasis to these projections. However, one must recognize that these computer models are based on assumptions, many of which need verification. Further improvements are needed in describing parameters such as clouds, water vapor and precipitation. Although these models have been improved over the last decade, significant further improvements are required before their results are reliable enough to be used in decision making.

In 1977, the Department of Energy and several other interested Federal agencies began a concerted effort to define the CO_2 issue. These efforts have grown and are now coordinated by the National Climate Program Office. This Office was established by the National Climate Program Act (P.L. 95-367) and is administered by the National Oceanic and Atmospheric Administration (NOAA). The national CO_2 program consists of research on the global carbon cycle, the effects of CO_2 on climate and the effects of climate change and CO_2 on the physical and biological environment. The program also addresses the costs and benefits of environmental change and ways to ameliorate the impacts of such change. Interagency budget planning, program review and coordination of research is handled through an Interagency Committee on Carbon Dioxide and Climate. This Committee was organized by the National Climate Program Office and is chaired by the Department of Energy, which serves as lead agency for investigating the CO_2 issue. In addition to DOE and NOAA, the other agencies involved in the program include the National Science Foundation, Department of Agriculture, National Aeronautics and Space Administration and the U.S. Geological Survey.

The National Academy of Sciences' independent assessment and oversight of the carbon dioxide research program should be very helpful. The Academy's expertise in the carbon cycle, climate modeling and possible environmental effects of increased CO_2 will be a significant contribution to the national CO_2 program. I and my staff have been working with the Office of Science and Technology Policy and the National Science Foundation to provide the support required.

The national CO_2 program as outlined in the FY 1980 Research Issues (DOE/EV-0129) document remains unchanged. Budget projections for FY 1982 have remained essentially unchanged between January and March. Of course, one should expect some shifts in emphasis within the overall program as we develop a better understanding of priorities in this research area.

Let me turn now to the Department's CO_2 program. Our goal is to run a solid, scientific program that addresses the relevant CO_2 questions. The DOE program focuses on three areas which require more research before the many CO_2-related questions can be answered. These areas include the global carbon cycle, climate effects, and environmental effects such as those on vegetation.

Before I discuss these research activities, let me comment briefly on the organizational alignment of the program. As a part of a recent Department-wide reorganization, the Office of Health and Environmental Research (HER), which was previously under the Office of Environment, was transferred to the Office of Energy Research. This brought all the Department's scientific research activities into one organization. Within the Office of Energy

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Research, the CO_2 program has been transferred from HER to the Office of Basic Energy Sciences which manages research in the physical sciences. This move reflects the fact that the most significant current scientific questions related to the CO_2 issue are in the realm of the physical rather than the life sciences.

As I noted a moment ago, the CO_2 program is working to improve scientific understanding in three areas. The first of these is the global carbon cycle. Additional information is needed if we are to understand the sources and sinks of CO_2. Simply put, where does it come from and what components of the climate system absorb it? The sources of CO_2, such as global fossil fuel usage, can be estimated with some accuracy. However, our scientific understanding of sinks, such as the uptake of CO_2 by the ocean, transfer to the deep oceans and the fundamental actions of the biosphere, requires significant improvement. Accordingly, much of our research currently is focused on defining and measuring the sources and sinks of the carbon cycle.

The second area we are addressing is that of climate effects. Research efforts have been expanded in an attempt to estimate regional and global changes in temperature and precipitation. These efforts are also aimed at identifying which climate changes over a several year period result from the effects of CO_2 as differentiated from the many other factors that could have been involved. The modeling effort in this area is aimed at understanding how the atmosphere and CO_2 effects on climate relate to the non-atmospheric components of the climate system such as oceans, land and the cryosphere. These relationships are not yet well understood. However, work is continuing with the General Circulation Models (GCM). This modeling effort is aimed at

developing predictions of temperature change for specific increases of CO_2. Work is also underway with atmospheric-ocean models where preliminary results suggest that a delay of a decade or more is introduced by the thermal inertia of the oceans into the effect of CO_2 on atmospheric temperature.

Although we should recognize that it may never be possible to attribute a climate change directly to atmospheric CO_2, it is important to explore methods for detecting, for the first time, the small changes amidst the many factors which affect the climate over a long period. Currently, temperature changes predicted by general circulation models cannot be identified because the natural year-to-year variability of the global average temperature (0.5 degrees C) is greater than that expected from the approximately 15% increase in CO_2 since the turn of the century. Research aimed at detecting a change in climate is aimed at enabling us to verify the atmospheric models by observing the effects they predict.

The third research area addressed by the DOE CO_2 program is that of environmental effects such as those on vegetation. In commercial greenhouses CO_2 is often used as a fertilizer to stimulate growth and under field conditions may increase crop yields. This CO_2 fertilization in the natural environment may be important in determing the biosphere's role in the carbon cycle. We have just entered into an interagency agreement with the U.S. Department of Agriculture to investigate direct effects of CO_2 on important field crops.

In summary, the CO_2 research and planning to date has identified specific tasks aimed at reducing uncertainties about atmospheric CO_2, possible

CO_2-induced climate changes, and CO_2 vegetation effects. In 1985 we plan to publish our first major report delineating what is known, unknown and uncertain in these areas. This effort will provide improved knowledge about long term implications of CO_2, but it is unlikely to achieve by 1985 definitive recommendations for policy options as to fossil fuel usage or proven mitigation strategies.

Clearly, a much better understanding of possible CO_2 induced climate changes and impacts is required. The difficult work of data collection and scientific study of CO_2 atmospheric, ocean, and biosphere interactions is vital to developing that understanding. We believe that our program design, execution and organization is sound and will enable us to begin to develop answers to CO_2-related questions that will be based on a solid, scientific foundation.

That concludes my testimony. I would be pleased to respond to questions.

STATEMENT OF JOHN MARCUM, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Mr. GORE. Our next witness is Dr. John Marcum, with the Office of Science and Technology Policy, with the Executive Office of the President.

Why don't you join him, Mr. Martin H. Belsky, Acting Director of the National Climate Program Office at NOAA, in the Department of Commerce.

Gentlemen, welcome. We will ask you to summarize your statements, which will be put in the record.

Dr. Marcum, if you could begin. We appreciate your patience throughout this long day, and we look forward to hearing from you.

Mr. MARCUM. Thank you, Mr. Chairman. I commend the committee as well for its interest in this issue and its stamina in seeing it through for such a long session. I will summarize my remarks, but there are some things that I think are worth repeating in detail in view of the concern demonstrated at the hearing earlier.

I would like to say at the outset I believe this problem does deserve serious study, and I am also concerned—and this has come up earlier—that so much media attention is focused on potential problems with nuclear energy, that it is important that we not lose sight of the potential cost that is maybe associated with accelerated use of fossil fuels, including the long-term CO_2 induced climate changes.

In the view of the administration, in meeting our future needs for increased electrical energy, the best strategy appears to be one of encouraging the private sector to move expeditiously to fuller utilization of our large natural resources of uranium and coal, while continuing government emphasis on longer term R&D in areas such as breeder reactions and fusion, which hold the promise for eventual energy self-sufficiency.

None of these areas is without costs, and it is important that the potential risks be evaluated carefully to avoid either underestimating or exaggerating their potential impact.

I would like to offer greetings to the subcommittees from the new Director of OSTP, who is Dr. George A. Keyworth, who was confirmed this past Friday by the Senate. He asked me to tell you that he considers the atmospheric buildup of CO_2 an important issue, and it is one we think should be taken into account in formulating an overall approach on energy policy.

I would like to begin by summarizing where the National Academy study that was called for in section 711 of the Energy Security Act of 1980 stands at this point, and I would also like to discuss the reasons for our delay in getting that going, since that study, together with the budget process in which we participate, will be the main device whereby we, here at OSTP, will channel our attention on this issue.

We have received from the Academy just this week a revised proposal—the National Academy of Sciences—to carry out the independent assessment of the CO_2 program requested by Congress last year. This was originally submitted in January and has been

revised to take into account comments received by other scientists in peer review, in the interim.

On the basis of the peer reviews, we did feel the original proposal had some serious flaws, and I would like to mention one or two of them. One of them, in fact, was a consensus that, focusing on a single expected-value scenario—so-called integrated scenario—would be premature and could lead to an unproductive effort, given the very large uncertainties involved on almost all aspects of the atmospheric CO_2 buildup.

Consequently, we suggested this study be redirected to include several alternative exploratory scenarios, and that the problems involved in the selection and description of the scenarios be carefully noted and, in addition, that the tendency for well detailed but low probability scenarios to take on a life of their own be taken fully into account.

We also felt, through eliminating some redundancy with ongoing Government programs and taking fuller advantage of existing international programs, that the total cost of this study could be brought into line with more constrained budgets which are available in the revised agency budgets as of our March revisions.

We are very pleased with the revised proposal.

The Academy has put together a first-rate group. You have heard today from two members of that panel, Dr. Revelle and Dr. Smagorinsky. Dr. Nierenberg, of the Scripps Institution, will be chairing the effort, and we are confident that the Academy panel will be able to provide the best possible response to the questions posed in section 711 of the Energy Security Act.

We also hope that by immediately beginning to assess the Government's CO_2 program which the Academy panel will do for us, that it will be able to help us make course corrections in the agency programs and in DOE and other involved agencies as needed in this fall's and next fall's budget reviews.

We are now in the process of concluding contract negotiations with the Academy, working out financial details over the next couple of weeks. We have worked out a funding scheme which will involve joint funding by the National Science Foundation and the Department of Energy, through an interagency transfer of funds, since our own resources in the Office of Science and Technology Policy do not permit us to independently fund such a large study on our own.

There were several questions which were proposed by Congressmen Scheuer and Gore in the July 20 letter to Dr. Keyworth, which I would like to comment on briefly. One is whether we have had an opportunity as yet to look into the detailed balance of the government's overall CO_2 research program.

We have not done that, but plan to do that in the context of this fall's budget review, which we participate in fully with OMB as a matter of procedure. This process is just now beginning.

Our initial reaction, based on our review to date, is that the most critical areas for further study are the physical phenomena involved in this issue. That is the global carbon cycle and climate modeling. We need to improve our models of the carbon cycle and the climate, if we are to understand the environmental impacts and social and political economic costs in more than general terms.

I think those general terms have been well laid out in earlier testimony and comments today.

Mr. SCHEUER. Would your new and improved model include some of the future socio-political-economic impacts flowing from the degradation caused by CO_2?

Mr. MARCUM. Yes, it would, as a matter of fact. What I am trying to say is I think in order to make those evaluations more relevant and to give us more confidence in what they tell us, we really need to understand better as a first priority the physical phenomena which are involved; but it will include both. And, in fact, the experts' panel that the National Academy of Sciences has put together on this, does include an appropriate representation of scientists in all areas.

Mr. SCHEUER. Social scientists?

Mr. MARCUM. Yes; as well as others.

Let me comment on the questions raised on OSTP's advising the President on this issue. Aside from raising the problem in general terms in the formulation of our overall energy policy which will take place this fall, we plan to wait for the findings of the Academy study before considering how best to advise the President on any policy implications of the buildup of atmospheric carbon dioxide.

In any event, we will take the panel's recommendations into account in assessing the appropriate government program in this area, consistent with section 711, paragraph D of the Energy Security Act, which calls for this assessment by the Office of Science and Technology Policy.

I would like to comment as well on the U.S. role and the international effort to understand the carbon dioxide problem. We believe that carbon dioxide is clearly a global issue, and it is important that the United States continue to play a leading role in this area.

It is my understanding we are already taking the lead in such organizations as the World Meteorological Organization, the United Nations Environment Program, and the International Council of Scientific Unions, in raising this issue and coordinating international scientific efforts.

Several of the panel members, including Dr. Smagorinsky, have been involved heavily in these international efforts, and we hope that through this personal involvement on the part of the panel members, that a study we are funding will include an appropriate evaluation of what is going on internationally, as well.

This concludes my prepared testimony, and I would be happy to respond to any questions.

[The prepared statement of Mr. Marcum follows:]

STATEMENT OF MR. JOHN MARCUM
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
TO THE
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
AND ENVIRONMENT
AND THE
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
JULY 31, 1981

Mr. Chairman and Members of the Subcommittees:

Thank you for inviting me to discuss the implications of the atmospheric build-up of carbon dioxide. I will say at the outset that I believe that this problem deserves serious study and I commend these Subcommittees for their foresight in bringing the CO_2 issue to the public's attention. Since so much media attention is focussed on the potential problems with nuclear energy, it is important that we not lose sight of the potential costs associated with accelerated use of fossil fuels, including long-term CO_2-induced climate changes. In meeting our future needs for increased electrical energy, the best strategy appears to be one of encouraging the private sector to move expeditiously to fuller utilization of our large natural resources of uranium and coal, while continuing government emphasis on longer-term R&D in areas such as breeder reactors and fusion which hold the promise for eventual energy self-sufficiency. None of these areas is without costs and it is important that the potential risks be evaluated carefully to avoid either under-estimating or exaggerating their potential impact.

The new Director of OSTP, Dr. George A. Keyworth, was confirmed by the Senate this past Friday and asked me to tell you that he considers atmospheric build-up of CO_2 an important issue. Neither of us are experts in this area and we look forward to improving our understanding of dimensions of this problem through our interaction over the next two years with the National Academy of Sciences' panel which will be carrying out the CO_2 study mandated by Section 711 of the Energy Security Act of 1980.

Let me begin by summarizing where that National Academy study stands and the reasons for its delay, since it together with the budget process will be the main device whereby we at OSTP will channel our attention on this issue.

This week we received from the Academy a revised proposal to carry out the comprehensive independent assessment of the national CO_2 program requested by Congress last year. This proposal has taken into account the comments provided by other scientists in a peer review of an earlier proposal submitted in January.

On the basis of the peer reviews, we felt that the original proposal had some serious flaws. There was a consensus that focusing on a single "expected value" scenario, as the NAS

proposed, would be premature and could lead to an unproductive effort given the large uncertainties involved on almost all aspects of the atmospheric CO_2 buildup. Consequently, we suggested to the Academy that the panel consider several exploratory scenarios, noting the problems involved in scenario selection and description, and the tendency for well-detailed but low-probability scenarios to take on a life of their own. We also felt that through eliminating some redundancy with other government programs and taking fuller advantage of on-going international activities, the total cost could be brought more into line with constrained funds available in the revised agency budgets.

We are very pleased with the revised proposal. The Academy has put together a first-rate group chaired by Dr. William Nierenberg of the Scripps Institution and including two members of today's panel, Dr. Revelle and Dr. Smagorinsky. We are confident that the Academy Panel will be able to provide the best possible response to the questions posed in Section 711 of the Energy Security Act and that they will do so by June 30, 1983, as called for in the legislation. We hope that by immediately beginning to assess the government CO_2 program, the Academy panel will be able to help us make course corrections, as needed, in the agency programs.

We will conclude contract negotiations with the Academy as rapidly as possible. Funds will be provided by the National Science Foundation and the Department of Energy for the NAS study through an interagency transfer of funds, since OSTP's resources for external contracts do not allow us to fund such a large study on our own.

Let me now try to address the other questions which Congressmen Scheuer and Gore specifically raised in their July 20 letter to Dr. Keyworth.

We have not yet had a chance to look in detail at the balance between the different elements of the government's CO_2 research program. We will do this with OMB, however, in the context of the FY 83 budget process which is now beginning.

Based on our initial review, our view is that the most critical areas for further study are the physical phenomena--the global carbon cycle and climate. We must improve our models of the carbon cycle and the climate if we are to understand the environmental impacts and social, political and economic costs and benefits in more than general terms. This is not to say that these latter dimensions of the problem should be neglected, but further advances in our understanding of environmental and social impacts clearly depend on better understanding of the physical systems involved.

Now let me comment on your question concerning the role of OSTP in providing the President with advice on the policy implications of the atmospheric CO_2 build-up. Aside from raising the problem in general terms in the formulation of our energy policy, we plan to wait for the findings of the Academy study before considering how to advise the President on any policy implications of the build-up of atmospheric CO_2. In any event, OSTP will take the panel's recommendations into account in assessing the appropriate government program in this area, consistent with Section 711(d) of the Energy Security Act.

Finally, let me comment briefly on the question concerning the US role in the international effort to understand the CO_2 problem. CO_2 is clearly a global issue and I believe it is important that the US continue to play a leading role in this area. I understand that we are already taking the lead in such organizations as the World Meteorological Organization, the United Nations Environmental Program, and the International Council of Scientific Unions in raising the issue and coordinating international scientific efforts. Dr. Smagorinsky, for example, has been heavily involved in several of these panels. Through such personal involvement the Academy study group which we are funding will monitor these international activities in responding to the mandate of Section 711 of the Act.

This concludes my prepared testimony. I would be happy to respond to any questions.

Mr. SCHEUER. We appreciate your testimony very much, Dr. Marcum.

In your study of the framework or the network of international agencies that are affecting this area, will you come to some determination as to whether there ought to be a clearer leadership role for one particular agency, or whether informal communication, based on a network that diffuses authority, is appropriate?

I don't see the lead horse in the international community. I see U.N. agencies like UNEP involved and doing very constructive work. I visited with them in Nairobi and have talked extensively with them. However, and with all due respect to UNEP, it is very difficult for a U.N. agency like UNEP to play a sharply focused leadership role in the community of international agencies. I have had enough operating experience working with them to be a little skeptical of their ability to lead and define clearly. I would like to get your view on that.

Second, I would like to get your view on whether environmental monitoring that is going on at all of these various diverse institutions and agencies, both nationally and internationally, is being sufficiently well coordinated and directed. Would something like the global environmental monitoring system that Congressman George Brown has taken the lead in presenting provide a more integrated global network and system into which these agencies can crank their findings and from which national governments can produce evidence and factor their findings? Is there a sufficient global network of research with common definitions and common standards so that as all of these various and diverse agencies and institutions produce data, it is cranked into a systematic schema? Do we have that system now, or do we need some kind of new structure or perhaps new agency for continuous and systematic global environmental modeling and research?

Mr. MARCUM. Let me respond to your first question initially. I share your concern that we should not rely on international organizations to provide the leadership needed in assessing potential risks associated with the atmospheric buildup of carbon dioxide. That is why, in my testimony, I did say I think it is important for the United States to assume and continue to play a leading role in the interaction with these international organizations.

What we need to do as a first priority is to do what we can to understand whether, in our view, our existing program is appropriate and adequate for this purpose and to determine as fully as possible our own priorities and views regarding its impact on energy policy, and then use that information in trying to best influence the international organizations which exist.

I do think that with regard to the question of global monitoring of the CO_2 buildup, that the data base which exists today clearly is much better than we have had in the past. If we had had the kind of monitoring over the previous century we have had in the last 23 years, then we would feel a lot more confident in trying to understand how to interpret the chart that has been the subject of so much discussion today.

At the same time, I think there is always a real need for an improved exchange of that data, a sharing of that data on an international basis, and this is particularly true as we begin to

consider whether there are any revisions in energy policy that we ought to take, and whether we think that it is important for other countries to take similar steps.

I would like to defer on the question of the technical adequacy of the monitoring in different areas and under different organizations to the next witness, who is much more familiar with those specific activities than I am.

Mr. SCHEUER. I am concerned with the adequacy of the present system. We have heard, and my experience leads me to agree, that there are great benefits from internal communications between a diverse collection of institutions and agencies at the national and international level. Undoubtedly, good things come from informal collaboration, conferences, and consensus making. I mentioned that I have had considerable experience with UNEP, and greatly respect their leadership. However, it is my perception that it is very difficult to get a U.N. agency to play a clearly defined leadership role with other international agencies, and to take the risks in clearly defining problems and in creating integrated research programs. It is very difficult for international agencies, particularly U.N. agencies, to play the clearly defined leadership role that I see as necessary and appropriate.

Is there a vacuum of leadership here? Even conceding the excellent work that is being done by this whole coterie of professional people working in this variety of institutions, is there a leadership role there? Furthermore, do we have a systematic, sophisticated means of reaching out and integrating all of the data that is being developed, internationally and nationally, into an integrated holistic research? Is there a need for a global environmental monitoring system that we don't have now that would help integrate and standardize the tremendous variety of information that we are producing?

As an underlying assumption, I would have to say "If it ain't broke, don't fix it." Change is expensive. If what we have now is quite sufficient, then the cost of adding something is a real cost that might not be justifiable. I would like to have both Dr. Smagorinsky and Dr. Schneider respond to this in your own ways.

Mr. SMAGORINSKY. Thank you, Mr. Chairman.

As Mr. Marcum said, the U.S. input into the international forum has many well-oiled outlets, through the U.N. agencies and also through other nongovernmental organizations such as the International Council of Scientific Unions, in which the U.S scientific community is very active. Also, there is the semiautonomous institution IIASA in Vienna, in which the United States has large interests.

If you are concerned whether a mechanism exists that has proven itself, there is, and that is the Global Atmospheric Research Program. GARP was somewhat lesser in scope but similar in its content. It was a creature of both a governmental organization, the World Meteorological Organization, as well as the International Council of Scientific Unions. GARP has proven itself over the last 13 years to work and work well, despite the deficiencies of international organizations.

Taking, as an example, the question of a monitoring strategy. This normally would be done through existing machinery in the

world climate program with international groups of experts. But this has yet to be done properly.

The difficulty now is largely scientific and technical rather than institutional, that is to identify the indices that can divulge an unambiguous signal of climate change. This could be done by a group of experts from the scientific community, for example convened by ICSU, which would come up with a set of monitoring specifications. At the point where one knows what should be done and how it should be done, one would follow the GARP pattern. Governmental representatives would then be convened say through the WMO or UNEP, or under the auspices of the U.N. as a whole. They would be empowered to commit national resources on behalf of their own countries.

That is the way it worked in GARP for say the global weather experiment. The WMO was the instrument by which national resources were brought in: satellites, ships, aircraft, buoys, balloons, and so on.

I submit that there is international machinery for integrating scientific expertise and national resources. The international organizations themselves handle very few moneys. It is usually only enough to have meetings and to maintain a small staff. But when it comes down to the expensive part of the enterprise, the nations themselves handle it in kind.

I think this can work well under the world climate program. It is complicated by two factors: One is that UNEP is involved and because of its term of reference UNEP is more difficult to deal with than some of the other U.N. organizations. But I hope that will straighten out, because UNEP has a lead role to play in the impacts area. The other factor is that some of the organizational facets of the world climate program have yet to be put into place.

At a meeting of the Executive Committee of the World Meteorological Organization several months ago, progress was made to solidify an organizational structure that could commit national facilities and resources. But I think in principle and based on past experience it can be made to work. I do not see a logical substitute for this modus operandi.

Thank you.

Mr. SCHEUER. For the current modus operandi?

Mr. SMAGORINSKY. That is right.

Mr. SCHNEIDER. I agree with what the doctor has said.

On one point he said the scope wasn't large. That is true. To clarify, the mechanisms now in place to deal with the physical science side are quite good and have worked remarkably well in the past, and probably will continue provided each national organization is able to meet in reality what it commits informally to do researchwise.

With regard to biological sciences, that is not in as good a shape as physical sciences because there is less experience on the carbon dioxide question. But that is getting better.

The social science side is one that is the least well organized. Yet, on the other hand, with UNEP taking an expanded role, there has been a meeting, there is an advisory committee, things are starting to move. It could be better. I do not think it needs to have

an organization so much as getting some action going, getting some funds from UNEP to actually fund good proposals.

So I am reasonably satisfied that the way the mechanisms are now set up certainly deserves a bit more of a chance before we would jump in and suggest organizational changes, and principally what we have to make sure of is that each nation makes its contribution to the goals of the international program.

Mr. SCHEUER. Do you feel that with a sufficiently comprehensive and clearly defined system of absorbing information and spewing it out, we can achieve a holistic and comprehensive research design which will enable us to make these critical public policy judgments that you tell us we are going to face in the near future?

Mr. SCHNEIDER. I wasn't as fully responsive to the two questions.

With regard to the second question, I do not think we have gone very far to setting up mechanisms to insure there will be holistic assessments. On the other hand, there is a real question as to whether that may be premature at the international level. There was an academy panel chaired by Tom Schelling and they pointed out, quite correctly, at international policy levels carbon dioxide can be a highly divisive issue and almost all of the scientific meetings where we get together even to analyze economic or social impacts, we are still not at the level of what people should do about it.

Mr. SCHEUER. Will you elaborate on that "highly divisive issue" phrase?

Mr. SCHNEIDER. For example, if one accepts at face value without further question prediction of certain climate models which say that the Midwest gets drier and the semiarid tropics gets wetter, you might find an awful lot of interest in having more carbon dioxide for people living in semiarid subtropics and a lot of concern for people in the Midwest.

High northern Canada or Siberia might be improved; the sea level rise might not hurt the Soviets so much, their admirals have for centuries been dreaming of warm-weather ports.

Mr. SCHEUER. How would it affect China?

Mr. SCHNEIDER. It is hard to know. If one takes almost any scenario you can name at face value, it is going to have some regions improved and some diminished. Some regions which have coal might not care about the environmental impact, selling the coal might be worth it; others might not. One can construct all sorts of scenarios of divisiveness.

So to raise this at the moment to an international group assessing the problem is likely to be almost counterproductive to the extent that sometimes people become afraid of the outcome of the research and therefore try to influence the research itself as a shadow motive for what they are doing. So as to avoid that wedge in the scientific community, I am reluctant to want to see anything more than national groups at this moment worrying about how we should react to CO_2 from an energy policy point of view. But I certainly wouldn't want to see international groups avoid the basic research questions of what could happen.

Mr. SCHEUER. I guess the same principle would apply to acid rain. Looking at the acid rain problem globally there are winners and losers. In Europe the prevailing winds are from south to north.

Scandinavia is suffering dreadfully from the pollutants that are produced in England and France and Germany which become acid rain. Our committee was over there in April, and visited these countries that are producing the pollutants. We found very little evidence that they were prepared to do anything about it.

Mr. SCHNEIDER. That is quite a bit more tractable case. I think the scientific evidence as to winner or loser as to cause and effect is a bit stronger than with regard to carbon dioxide at this stage, even though there are a lot of scientific uncertainties.

Mr. SCHEUER. Yes. In the case of Canada, President Reagan found out very early in his term that the Canadians were absolutely enraged about the contribution that our Midwestern utilities are making to acid rain in the Northeast of the United States, as well as in Canada. In Canada, of course, the forest products industry and the fishing industry that are affected by acid rain are far more important in relation to their total GNP than they are in this country.

I was in Halifax a couple of weeks ago meeting with Canadian parliamentarians on the subject and I happened to turn on the television when Prime Minister Trudeau was answering questions from the Members of Parliament. I would say two-thirds to three-quarters of the questions that he was asked bore on Canada's relations with the United States and the overwhelming physical presence of the United States on every aspect of their society. A good third of them were on the question of acid rain. They tell me that 75 percent of the Canadian population knows that acid rain emanating from the United States is having a devastating impact on Canada's lakes, streams, forests, forest growth, forest products industry, and croplands. I doubt if 1 percent of the population of our country knows about the potential impact of acid rain on our country, much less Canada.

Mr. SMAGORINSKY. Mr. Chairman, I would like to go back to one point regarding the international mechanisms. For them to work, they do require strong financial support from national resources. Traditionally the United States, for example, has supported the U.N. and its technical agencies. We have also substantially supported the International Council of Scientific Unions and IIASA in Vienna. The latter two are funded through the National Academy of Sciences, from grants given by NSF and other agencies of the Federal Government.

The U.S. support has always been very important. Within the last year the support has seriously wavered, almost to the point of endangering the continued existence of some of these organizations. At the very least it may result in greatly reduced programs, probably including work on the carbon dioxide question.

I think it is within the U.S. interests to insure its continued modest support. It probably amounts to several tens of million dollars altogether, for all of these organizations. If we are really serious about being able to influence and get the assistance of international organizations—then we must support them.

Mr. SCHEUER. Well, you make an excellent point. I am trying to make a distinction between the actions of the General Assembly, and the very useful constructive work done by a whole variety of specialized agencies of the UN. To the average member of the

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public, that is a distinction without a difference. They don't understand it and, they aren't interested. However, I fully agree with you—I am quite familiar with the work of a number of the UN agencies. It would be a tragedy if they are wiped out through inadequate funding.

STATEMENT OF MARTIN BELSKY, ACTING DIRECTOR, NATIONAL CLIMATE PROGRAM OFFICE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Now we will go to our last witness, Mr. Martin Belsky, Acting Director of the national climate program.

Mr. Belsky, first let me apologize to you for the long delay in hearing you. Thank you for your patience and tolerance. It has been the end of a long day of hearings.

Your testimony will be printed in full in the record. So you might want to chat with us informally for 10 or 15 minutes and we will have some questions for you.

Mr. BELSKY. I feel like the sherbet which was ordered before dinner. After a big lobster dinner, you are not so sure you are still wanted.

I have in my prepared testimony a lot of detailed comments about the purpose of the carbon dioxide program, and how it fits into the national climate program. I do again want to say to this committee that this committee is responsible, I think, for the national climate program and clearly for one of the principal thrusts of the national climate program, which is that titled carbon dioxide, environment, and society. It is one of the major elements of the national climate program.

You have heard already how DOE is the lead agency responsible and how it has organized and set up a subcommittee of the Climate Board called Carbon Dioxide and Climate, which I am glad to hear now will have a meeting in September to decide the future.

I have attached to my testimony two documents which might be useful. One is a chart which came out of the same red book which lays out the way the CO_2 money was broken down, and the other is the description of the carbon dioxide principal thrust. Again, these were prepared in the last administration, but many of the elements we heard today will be continued.

We believe that the major issue for the carbon dioxide element of the national climate program is that it continue to be a collective effort. As you can see, there was approxiamtely $24 million in this year's budget for all the Federal agencies involved in the carbon dioxide effort. Of that DOE had $14 million, more than 60 percent.

That is a tremendous growth from the earlier amounts. DOE spent about $6 million of the total $15 million in 1980. It is an enormous growth in the carbon dioxide program in the Federal Government. It indicates there has been a deliberate expansion up to now of federally supported studies of climate as it may be affected by carbon dioxide increases.

This was an intentional effort made by all the agencies in the Federal Government working through the national climate program and putting together a comprehensive program.

As you have heard repeatedly today, and I will highlight again, the issue is not one just of importance to the United States; it is of global concern.

The reason it is of global concern is essentially because what we do in the United States has to affect what will happen in the world. But more important, what happens in the world will also impact the United States. Even if we were to make massive changes in our energy program and policy to handle supposed effects of carbon dioxide increase, nevertheless, if the world community did not respond in the same manner, it would be to little avail.

So we have to be very careful to put together a very comprehensive international program. Let me interject, there is a chart which you asked some of the questions about. The person responsible for this chart is in the audience, also from NOAA, Les Machta from Air Resources Laboratory, who is also an expert, as is Dr. Smagorinsky.

Again, he and Dr. Smagorinsky are two of the principal scientists in NOAA for atmospheric issues, particularly on climate—people I am proud to say are in the Federal Government working in behalf of the public to contribute to our knowledge about what goes on in climate. I wanted to call them to your attention.

Let me talk a little about the global program. There is in fact a world climate program being developed. One of the aspects of that program is the world climate impacts study program which is the responsibility of UNEP. But UNEP, ICSU, and WMO are working together for a world climate program. They are getting together, and they are getting together under the impetus of what they perceive to be the concerns of Congress and other legislators around the world, and the public, and they are trying to put these things together to prepare a comprehensive program.

Just as we are still in the planning and experimental stage of the national climate program, I believe we are also in the planning stage of the world climate program, but I am optimistic. In fact, there is going to be a major international study conference on carbon dioxide assessment methods, which is scheduled to be held in 1983, next year.

Mr. SCHEUER. 1983 is not next year.

Mr. BELSKY. The year after that.

Mr. SCHEUER. I think we heard about that. Where will that be held?

Mr. SMAGORINSKY. It might be at IIASA, in Vienna. IIASA.

Mr. SCHEUER. The International Institute for Applied Systems Analysis [IIASA]?

Mr. BELSKY. The United States is expected to be a major participant at this conference. All the Federal agencies are getting together, including DOE, deciding how we can contribute to the world effort going on.

I want to spend a few minutes going over two of the things that I thought might be of interest to you.

You can see in the attachment the original proposal for the National Program on Carbon Dioxide, Environment and Society.

You heard today from both OSTP and the DOE that they plan to do this in a staged process. That is, the first area they want to

concentrate on is research in the carbon cycle and research in carbon dioxide on climate. They are emphasizing those two areas of the six areas involved.

The research on the effects of climate, the research into social, political, economic costs and/or benefits of climate, research in the amelioration of global and sectoral impacts, are areas that in their opinion are questions that have to be addressed after we get the basic information from the first two segments.

Mr. SCHEUER. Did they make clear what their timetable was for achieving that progress in their data base so that they could begin to investigate some of these other areas?

Mr. BELSKY. No. As a matter of fact, one of our hallway conversations today was when they would be prepared to present that to the interagency subcommittee. They said they planned to give not only a budget estimate but an informal timetable about how they are going to stage this process.

Mr. SCHEUER. And when will that be?

Mr. BELSKY. They said they are going to make that presentation to us in September so they could make it to you in October.

Mr. SCHEUER. Very good.

Mr. BELSKY. One of the things that we have to now decide in light of the new administration and its new goals and priorities, is what does that mean to the national climate program? The national climate program has to be revised every other year. That means it is due in 1982 for revision.

We would have to sit down as part of that process and decide, are the goals and milestones set out in the plan realistic? Should they be changed or given different emphasis?

I fully expect this subcommittee to look over our shoulders as part of their oversight responsibility to see whether we are doing an appropriate job in assessing those impacts.

I really don't have much more to say except I believe that this committee, both in drafting the National Climate Program Act and convening meetings and hearings like this, serve not just the agencies involved but the national climate program as a totality. It forces us, besides going to interagency meetings, to get our interagency act together and come before this committee and say here is what we are doing across the board, OSTP sitting down with DOE, sitting down with NOAA, with the national climate program, and saying, here is where we have to go.

One of the questions asked today is, will the other agencies or will the private community pick up the slack?

Mr. SCHEUER. Which agencies are you speaking of?

Mr. BELSKY. Other agencies that could do it. NSF has responsibility for funding some research grants. EPA is now for the first time getting involved in the question of carbon dioxide. NOAA of course has a very large role.

Those are some of the questions that we have to sit down collectively to coordinate our efforts and decide.

Again I am an optimist about the national climate program. I believe we have made a very good effort. I believe we can have the opportunity and the time to sit down and prepare such an analysis and come back to you and present it to you.

Thank you for your time.

[The prepared statement of Mr. Belsky follows:]

TESTIMONY OF MARTIN H. BELSKY
ASSISTANT ADMINISTRATOR FOR POLICY AND PLANNING, AND
ACTING DIRECTOR, NATIONAL CLIMATE PROGRAM OFFICE,
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

BEFORE THE
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH AND ENVIRONMENT

AND THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY

OF THE
U.S. HOUSE OF REPRESENTATIVES

JULY 31, 1981

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEES, it is a special pleasure for me to appear before you today and describe the National CO_2 program and its relationship to the National Climate Program. The Science and Technology Committee and the Senate Commerce Committee were responsible for the National Climate Program Act and are therefore the architects of the National Climate Program. One of the reasons for your concern about climate was the disturbing information that was brought to your attention about the so-called "greenhouse effect" - the warming trend which is expected to result from increases of carbon dioxide (CO_2) in the atmosphere. Not surprisingly, therefore, one of the priorities of the National Climate Plan, is "CO_2,

Environment and Society". The goal of this priority is to assess the impacts of the climate changes that could be caused by continued increase in atmospheric CO_2 and to evaluate potential response strategies. Leadership responsibility for this Principal Thrust has been assigned to the Department of Energy. DOE has been playing a prominent role in CO_2 research since 1979 and the National Climate Program Office, and other federal agencies, have had a close working relationship with DOE in assuring implementation of the tasks and milestones established by the Climate Plan for the CO_2 Program. I am attaching to my testimony the Chapter of the Plan describing CO_2 principal thrust, its purpose, and goals.

CO2 and The National Climate Program

The 1978 National Climate Program Act established a National Climate Program "to understand and respond to natural and man-induced climate processes and their implications." The Program is an interagency one, involving all interested and affected Federal agencies. The agencies form a Board of Directors, called the Climate Policy Board, which develops, reviews and revises the Climate Program. The Program is administered by the National Climate Program

Office. NCPO acts as the staff for the interagency Policy Board and is the focal point for the planning and coordination of the Nation's climate-related activities.

The Program is guided by a 5-Year Plan, developed by NCPO and approved by the Climate Policy Board. The Plan is the basis for the structure and management of the National Climate Program. The Plan establishes the goals of the national program. Highest priority goals and missions are called Principal Thrusts. These are joined by other areas of climate program concern and general climate and climate-related activites in the continuing Climate Program. Each of the Principal Thrusts involve many disciplines and many federal agencies. To assure coordination, a lead agency is asigned responsibility. The overall strategy of the Plan is to emphasize early production of useful information based on our knowledge of climate, while simultaneously expanding our understanding of climate.

The CO_2 program has been and we hope will continue to be one of the successes of the National Climate Program. DOE has assumed responsibility for the Principal Thrust and works with many federal agencies in developing a multi-agency, multi-discipline program. Coordination is provided by an Interagency Committee for CO_2 and Climate -- really a subcommittee of the Climate Policy Board. Led by DOE, the Interagency Committee has looked at the various activities

activities of the agencies and developed tasks, milestones and issues to be addressed. In 1980, the Committee compiled and approved the publication entitled "Research Issues and Supporting Research," a detailed view of the nation's effort in addressing the carbon dioxide concern.

The federal CO_2 Program involves most of the Federal agencies having climate responsibility and many of the scientific disciplines. DOE, the lead agency, has energy development as its mission. By necessity, part of that mission is to develop means to determine potential effects, of such development such as the CO_2 increases.

Other agencies which have been active in the CO_2 area include National Oceanic and Atmospheric Administration (NOAA) for monitoring and prediction; National Science Foundation (NSF) for paleoclimate and oceanic studies and impact assessment methods; Environmental Protection Agency (EPA) for environmental impact assessment and policy analysis; Department of Agriculture (USDA) for biological implications of CO_2 increases; National Aeronautics and Space Administration (NASA) for modelling; United States Geological Survey (USGS) for paleoclimate studies, and Department of State (DOS) for facilitating international cooperation.

The CO2/Climate Concern

Other witnesses today will describe in more detail the latest scientific knowledge and questions about CO_2 increases in the atmosphere. Let me summarize briefly the interest of the National Climate Program in the CO_2 issue and the goals of the National Climate Plan in responding to those issues.

First, it is known that atmospheric levels of CO_2 have been increasing and it is generally beleived that they will continue to rise well into the next century as a consequence of the world's fossil fuel-based energy economy. Second, a buildup of atmospheric CO_2, if it continued to occur must be regarded today as irreversible. There is no known commercially feasible method of artificially removing CO_2 from the atmosphere. Third, it is well accepted that atmospheric CO_2 acts to warm the atmosphere by absorbing heat radiation from the earth's surface, preventing it from dissipating into space, the so-called "greenhouse" or "warming effect", I mentioned earlier. However, CO_2 is only one factor affecting temperature and climate, and it is extemely difficult to isolate its effect on climate fluctuation. Finally, our CO_2 effort must be global in scope. Our understanding of the global climate system rests only in

part upon our comprehension of the CO_2 effect. Our understanding of the CO_2 effect depends entirely upon our comprehension of the global climate system.

CO_2 has become an issue and I must stress that it is an issue, that while subject to concern, is still not resolved. Some believe that significant climate changes will result from the world-wide increase in the atmospheric concentration of the gas. Others believe that we not act precipitously in response to a still unknown impact. What is sure is that in order to properly carry out our responsibilities for administration of the national research effort and ensure our country's informed response to changes in climate, wherever they may occur around the globe, we must know a great deal more.

Overall program policy guidelines have been established by the National Climate Plan to define the strategy for the National Program on "CO_2, Environment, and Society." Quoting directly from the 5-Year Plan:

- o The Program must be comprehensive and interdisciplinary. The traditional bounds of climate research, economic research, environmental research must be transcended to allow policy issues to be addressed in all their aspects. Cooperation among disciplines - especially between the physical and social sciences - must be fostered throughout the planning and execution phases of the Program.

- Several areas of research relevant to CO_2 and Climate are already very active. The Program will supplement these activities only as necessary to ensure their adequacy, while exercising leadership to support promising new activities in less developed fields.
- Review, integration, and evaluation of progress and the identification of policy options and their consequences must be part of the total program effort.
- The CO_2 and climate effort must involve extensive collaboration among agencies and between Federal and non-Federal organizations, but with a single focus for planning and leadership.
- The CO_2 question is fundamentally an international issue. The climate context is global, and the policy options must be globally conceived. National policy on CO_2 emissions, in itself, must necessarily fall far short of confronting the global issue. Therefore, the National Program will strive to maximize international cooperation in relevant climatic, environmental, and policy research; data gathering and analysis; and information dissemination and assessment.

The CO2 Budget

DOE has had that lead agency responsibility for CO_2. They have indicated to the Climate Office that they will continue to live up to their responsibility in planning, leadership, and funding. The DOE role has been not just limited to its own agency budget. They have worked with the National Climate Program Office and the National Science Foundation in going to the climate community, and especially the National Academy of Sciences Climate Board, to secure expert research not just on the atmospheric science questions of cause and effect but also on the social, economic, and political science questions of potential risks, impacts and costs.

DOE was instrumental in developing and securing the approval of the 1980 publication "Research Issues and Supporting Research", I described earlier. This document includes a multiagency budget by major CO_2 research elements for the years FY80 - 82. A summary of the budget is attached to my testimony as Table 1. The budget reflects the collective government judgment on the appropriate budgetary balance between the basic elements of the CO_2 program, namely, research on the global carbon cycle; climate modeling; potential environmental effects; social,

political, and economic costs and benefits; and the amelioration of impacts.

It indicates that there has been a deliberate expansion of Federally-supported studies of climate as it may be affected by carbon dioxide increases.

Table 1 indicates that over 15 million dollars was spent on the CO_2 priority in 1980. Of this, DOE spent 6 million or about 40%. Over twenty-one million is proposed for 1982 with DOE responsible for over 15 million or about 71%. Other major agencies include NSF, (13.5% in 1982), and NOAA (12% in 1982).

International Cooperation

As I have indicated, the Climate Plan also stresses that it is essential to view CO_2 within a global context.

The U.S. has led the world in documenting the increase and in supporting research attempting to explain the rise in CO_2 and predicting what it may portend for the earth's climate.

For a number of years obervations have been made of carbon dioxide in the relatively clean air over Hawaii. They show at least in this one region far removed from major industrial sources, that carbon dioxide is increasing.

These early studies were pioneered by scientists from Scripps Institution of Oceanography and funded by the NSF. Observations over Scandinavia, Antarctica, and other remote sites have confirmed that the observed increase was world-wide. Today, NOAA maintains baseline measurements at several stations at locations ranging from Point Barrow, Alaska, to Mauna Loa, American Samoa and the South Pole. Based on the records obtained so far, it is possible that a doubling of atmospheric carbon dioxide from the levels measured in 1957 can occur within our lifetime if current trends continue. While there is nothing magic in this level, it is of sufficient magnitude to have caused atmospheric scientists at the Geophysical Fluid Dynamics Laboratory of NOAA to look at this critical atmospheric constituent, and at what such an increase might do to the global climate. Their report, published in 1975, added impetus to our concerns, and made a convincing argument for establishment of the CO_2 Principal Thrust and increasing resources to CO_2 research.

Global concerns require and deserve international responses in policy making as well as scientific endeavors. For that reason, the National Climate Program Act stresses the need for "global data collection, and monitoring and

analysis activities." The National Climate Program Office is charged to work with other Federal agencies in "coordinating the activities of the Climate Program with the climate programs of other nations and international agencies and organizations." Towards this end, NCPO and other Federal agencies are participating in the planning and development of the World Climate Program. The World Climate Program (WCP) was formally established in 1980 under the leadership of the World Meteorological Organization (WMO). The WMO, together with the United Nations Environment Program (UNEP), and the International Council of Scientific Unions (ICSU), are establishing the operational network essential to the success of the contributing programs of member nations. Carbon dioxide has been a major area of concern within the World Climate Program since its inception. Indeed, a major international study conference on CO_2 assessment methods under the auspices of the WCP is now scheduled to be held in 1983. The United States is expected to be a major participant in this convocation which is intended to facilitate an orderly international dialogue on the implications of CO_2 and the global climate system.

Conclusion

It has taken nature millions of centuries to deposit vast quantities of carbon in the earth's surface. Today, due to

man's extensive advances in technology and economic development, this same carbon is being returned to the atmosphere a million times more rapidly. The global climate system is by nature dynamic and constantly changing. However, we believe it has never been subjected to such a rate of change in one of its fundamental constituents. This phenomenon demands our serious concern but not alarm. It means a continuing commitment to determine the true nature of the changes and response. This national commitment is what is meant by the mandate expressed by the National Climate Program Act's purpose "to assist the Nation and the world to understand and respond...to man-induced climate processes and their implications."

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TABLE 1

PROGRAM SUMMARIES (FY 80-82)

National Program on Carbon Dioxide, Environment and Society

(In Millions of Dollars)

Program Budget Elements	DOE			NASA			NOAA			NSF			USGS			TOTAL BY ELEMENT			PERCENTAGE BY ELEMENT		
	80	81	82	80	81	82	80	81	82	80	81	82	80	81	82	80	81	82	80	81	82
I. Carbon Cycle	3.8	4.7	5.7	-	-	-	1.3	1.5	1.6	5.8	4.4	2.4	.5	.6	.6	11.4	11.0	10.2	74.2	59.8	47.4
II. CO_2 and Climate	1.0	1.8	2.6	.1	.1	.1	1.0	1.0	1.0	.3	.4	.2	-	-	-	2.4	3.3	4.0	15.9	17.9	18.2
III. Effects of Climate Change and CO_2 Increased on the Environment	.2	1.3	3.3	-	-	-	-	-	-	.3	.3	.3	-	-	-	.2	.7	1.0	3.3	8.8	17.0
IV. Social, Political and Economic Costs and/or Benefits of Global Environmental Change	.2	.7	1.0	-	-	-	-	-	-	-	-	-	-	-	-	.2	.7	1.0	1.4	3.7	4.5
V. Amelioration of Global and Sectoral Impacts	0	.4	.7	-	-	-	-	-	-	-	-	-	-	-	-	-	.4	.7	.3	2.2	3.1
VI. Review, Integration and Evaluation (Assessment)	.2	.8	1.3	-	-	-	-	-	-	-	-	-	-	-	-	.2	.8	1.6	1.5	4.3	7.4
PROGRAM TOTAL	6.0	10.2	15.3	.1	.1	.1	2.3	2.4	2.5	6.5	5.1	2.9	.5	.6	.6	15.4	18.5	21.5	100.0	100.0	100.0

CHAPTER IV

RESPONDING TO IMPACTS AND POLICY IMPLICATIONS OF CLIMATE

The Climate Program must identify impacts on climate by man and impacts of climate on man. This information is needed in forming policies to handle such impacts.

Principal Thrust	Lead Agency
Carbon Dioxide, Environment, and Society	DOE
Climate and World Food Production	USDA
Area of Program Concern	**Participating Agencies**
Climate-Related Hazards	USDA/DOD/NSF/FEMA/DOI/NOAA
Energy Production, Distribution, and Demand	DOE/NOAA
Impact Assessment Methodologies	DOE/USDA/NOAA/EPA/NSF
Regional Climate Effects of Humans	DOE/EPA/USDA/NOAA/NSF
Semiarid and Arid Lands	DOI/USDA
Water Resources Management and Planning	USDA/DOD/DOI/EPA/DOC

A. Principal Thrusts

1. Carbon dioxide, environment, and society

The ability to predict the agricultural, environmental, and societal consequences, both national and international, of increasing atmospheric concentrations of carbon dioxide (CO_2) must be developed to permit informed policy decisions to be made on the use and development of energy and other resources. This goal necessarily implies identifying and evaluating the implications of a wide range of energy and resource policy options.

Need

Systematic observations begun more than 10 years ago have shown a steady increase in atmospheric CO_2 concentrations. A 1977 National Academy of Sciences report (Geophysics Research Board, 1977) concluded that "the climatic effects of carbon dioxide release may be the primary limiting factor on energy production from fossil fuels over the next few centuries." A more recent report by an Academy panel (Climate Research Board, 1979b) found "no reason to doubt that climate changes will result" if CO_2 continues to increase, "and no reason to believe that these changes will be negligible."

There is a consensus in the scientific community that carbon dioxide from the unrestrained combustion of fossil fuels is potentially the most profound environmental issue facing mankind. What society now chooses to do, or not to do, can profoundly affect the environment and society a few decades hence. Our energy strategy must be chosen with consideration of these effects—and with much care.

What is the rate at which atmospheric CO_2 concentrations are increasing and will increase in the future? Observations made at such diverse locations as the South Pole, Samoa, Hawaii, and Alaska demonstrate unequivocally that the increase is global. Over the last two decades the rate of increase has been getting larger, paralleling very closely the rate at which fossil fuels have been burned throughout the world.

About one-half of the CO_2 produced through combustion of fossil fuels seems to remain in the atmosphere. The remaining CO_2 must be taken up in the larger CO_2 reservoirs —the biosphere or the oceans. Some scientists believe that the biosphere has been a source and not a sink of CO_2. They contend that as forests are cleared and the soil tilled the biospheric storage of CO_2 is substantially reduced. As the wood and organic matter in the soil burn or decompose, CO_2 is then released to the atmosphere. The magnitude of this effect is not well known, and some doubt its significance.

The rate at which the oceans can act as a sink for the added CO_2 is also in doubt. The cold deep waters of the world oceans could easily absorb the CO_2 produced by burning fossil fuels, but the warmer upper layers of the oceans are nearly saturated with CO_2 and are very nearly in equilibrium with the atmosphere. For the oceans to take up excess CO_2 there must be mixing downward to the deep waters from the warmer upper layer, and most ocean circulation models indicate that this is a very slow process.

We must analyze the entire global carbon cycle to project how rapidly atmospheric CO_2 concentrations will continue to increase. Almost all models suggest that some time in the 21st century, atmospheric CO_2 will be double its preindustrial value. Some suggest that this will occur early in the century (say, 2030), and some say later (say, 2060).

How will increased CO_2 alter climate? CO_2 is a gas that absorbs and reradiates infrared radiation. Along with other such gases, the most important being water vapor and

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ozone, it plays a very significant role in maintaining the present climate. Calculations of the direct net heating—the "greenhouse" effect—resulting from doubling CO_2 and altering nothing else imply a warming of surface temperatures by 1° C. But it is impossible to double CO_2 and alter nothing else. Warmer surface temperatures would tend to increase the water vapor content of the atmosphere, which would about double the warming effect of the CO_2. Other possible alterations resulting from CO_2 increases—"feedback" mechanisms—include changes in the radiative effects of clouds, snow, and ice, and the circulation and transport of heat and momentum by the oceans and the atmosphere.

The NAS Panel (Climate Research Board, 1979b) examined in some detail numerous models incorporating various feedback mechanisms. Their report states:

> "We conclude that the predictions of CO_2-induced climate changes made with the various models examined are basically consistent and mutually supporting. The differences in model results are relatively small and may be accounted for by differences in model characteristics and simplifying assumptions . . . . If the CO_2 concentration of the atmosphere is indeed doubled and remains . . . long enough . . . our best estimate is that changes in global temperature of the order of 3° C will occur and that these will be accompanied by significant changes in regional climatic patterns."

More analysis is needed of the nature and magnitude of these changes in regional climatic patterns. Regional temperature and precipitation characteristics—their means, seasonal patterns, and year-to-year variability—are likely to be more severely affected than global mean temperature. Models are now able to give only a few tentative indications of the regional climatic effects of future increases in CO_2. Although the models generally agree that warming will be more pronounced at high latitudes than at low ones, regional effects are more complicated and varied than a simple variation with latitude. The models indicate that precipitation patterns will be affected, but their representations of oceans and other physiographic features are too crude to permit much reliance on their results.

How will the increase in CO_2 affect the rest of the environment, either directly or together with climate changes? In this context, the environment includes natural terrestrial and marine ecosystems. It also includes the managed biosphere—agricultural and grazing lands and forests—the cryosphere, and ocean circulations.

Little overview of the environmental consequences of increasing CO_2 is available. Some analyses have been made of effects in particular areas, such as agriculture, ecology, and oceanography, but these analyses have never been integrated across disciplines or related in a comprehensive overview.

A recent workshop held by the American Association for the Advancement of Science for DOE was perhaps the first interdisciplinary gathering to address these issues. Some of the concerns that were identified included:

- Ocean phenomena—How would ocean circulation or biogeochemical changes in turn affect the formation of bottom and intermediate waters?
- Cryospheric behavior—Would warmer ocean and air temperatures tend to dislodge a huge Antarctic ice sheet, causing a cataclysmic rise in sea level?
- Effects on the unmanaged terrestrial biosphere—How would species and ecological systems respond to high levels of CO_2 and altered climate?
- The managed biosphere—What might be done to improve the adaptability of the agricultural system?

What will be the social and economic consequences of increased CO_2? It is not sufficient to consider only net effects. Who is affected, and when, may be overriding issues. This is an extremely difficult question and would be so even if the direct physical and biological effects could be delineated. A major source of that difficulty is the need to assess what the Nation's and world's social and economic situation will be 50 or 100 years hence.

What are the options available to ameliorate the unwanted effects and impacts? Possible alternative actions include minimizing the buildup of atmospheric CO_2 and minimizing undesired effects by adapting to their consequences. These options must be identified and their implications evaluated in the light of all the climatological, environmental, economic and other relevant information available. It is not now evident that any major actions are warranted.

Lead Agency

Leadership responsibility for this Principal Thrust is assigned to DOE, which has, in effect, been carrying out that leadership responsibility since 1977 by establishing advisory bodies, organizing planning teams and workshops, and supporting relevant research.

To support DOE, the National Climate Program Office has established, under authority of Section 5 (e)(2) of the National Climate Program Act, an Interagency Committee for CO_2, Environment, and Society. This committee, chaired by the Manager of the DOE CO_2 Research and Assessment Program, will serve as a formal body for coordinating the CO_2 efforts of the various Federal agencies. One of the major functions of this committee will be to facilitate multiagency participation in the planning as well as in the research.

Several agencies, all represented on the Interagency Committee, will be directing their own research activities, often supported by pass-through funds from DOE. DOE will receive their reports and information and be responsible for comprehensive evaluation and planning.

Planning for international activities, especially those that involve multinational organizations and institutions,

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will be carried out through the National Climate Program Office to assure consistency with other international climate activities. Those closely involved with the CO_2 Program will, of course, suggest initiatives and participate in international planning activities.

National Program

Several guidelines have been established that serve to define the strategy for the National Program on Carbon Dioxide, Environment, and Society:

- The CO_2 question is fundamentally an international issue. The climate context is global, and the policy options must be globally conceived. National policy on CO_2 emissions, in itself, must necessarily fall far short of confronting the global issue. Therefore, the National Program will strive to maximize international cooperation in relevant climate, environmental, and policy research; data gathering and analysis; and information dissemination and assessment.
- The Program must be comprehensive and interdisciplinary. The traditional bounds of climate research, economic research, environmental research must be transcended to allow policy issues to be addressed in all their aspects. Cooperation among disciplines—especially between the physical and social sciences—must be fostered throughout the planning and execution phases of the Program.
- Several areas of research relevant to CO_2 and Climate are already very active. The Program will supplement these activities only as necessary to ensure their adequacy, while exercising leadership to support promising new activities in less developed fields.
- Review, integration, and evaluation of progress and the identification of policy options and their consequences must be part of the total program effort.
- The CO_2 and Climate effort must involve extensive collaboration among agencies and between Federal and non-Federal organizations, but with a single focus for planning and leadership.

DOE has prepared a detailed plan on CO_2 research and assessment entitled "A Comprehensive Plan for Carbon Dioxide Effects Research and Assessment, Part I." The plan is the outgrowth of an extensive process that has involved a large number of scientists, including many from abroad.

The plan is complete with regard to research on the global carbon cycle and the effects of increasing carbon dioxide on climate, and a first revision is being prepared. Part II of the plan, dealing with the effects of a CO_2 increase and climate system change on other parts of the environment and on society, is being developed. Definition of the review, integration, and evaluation (assessment) program has begun, but is not yet documented. The program planning related to amelioration and adaptive strategies has not yet begun in a formal sense. There will be concentrated efforts in 1980 to complete the planning regarding environmental and societal effects, allowing major programmatic activities to be initiated in FY 1981.

Table 6 gives the outline of the comprehensive research program. This table indicates the five major research categories, one corresponding to each of the significant aspects of the Principal Thrust, plus a sixth category for the very important assessment function. An unpublished 1979 Department of Energy working document entitled "Research Issues" contains more detailed statements of program content and priority for various issues and subcategories and summaries of relevant research projects supported by various agencies.

Milestones

Significant milestones for this thrust draw upon the more complete list in DOE working documents. The milestones depend upon continuing programmatic efforts in several agencies, but DOE will support most of the incremental effort. Many, but not all, of the milestones listed here refer to DOE activities. This will change as the roles of other agencies become more explicit and comprehensive.

FY 1980

- Begin feasibility study of remote sensing of global biomass.
- Make operational the NOAA/DOE worldwide network for monitoring CO_2.
- Begin major investigation of ocean mixing in the North Atlantic (Transient Tracers in Oceans Program, jointly supported by NSF and DOE).
- Hold workshop on CO_2 and the West Antarctic ice sheet.
- Complete observational phase of equatorial Pacific CO_2 Program (FGGE).
- Begin climate model studies with coupled ocean/atmosphere models.
- Begin assessment program.
- Publish draft program plan for research on the environmental and societal consequences of CO_2 increases and climate change (Research Categories III and IV).

FY 1981

- Make biomass measurement field test in tropical forest.
- Begin feasibility studies to estimate total ocean/organic carbon pool.
- Initiate CO_2 ecosystem fertilization studies.
- Begin funding research on the environmental effects of CO_2 increase and climate change on the managed and unmanaged biosphere.
- Begin funding research on social, political, and economic costs and/or benefits of global environmental change.
- Publish plans for research on amelioration and adaptation (Research Category V).

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Table 6.—A National Program on carbon dioxide, environment, and society

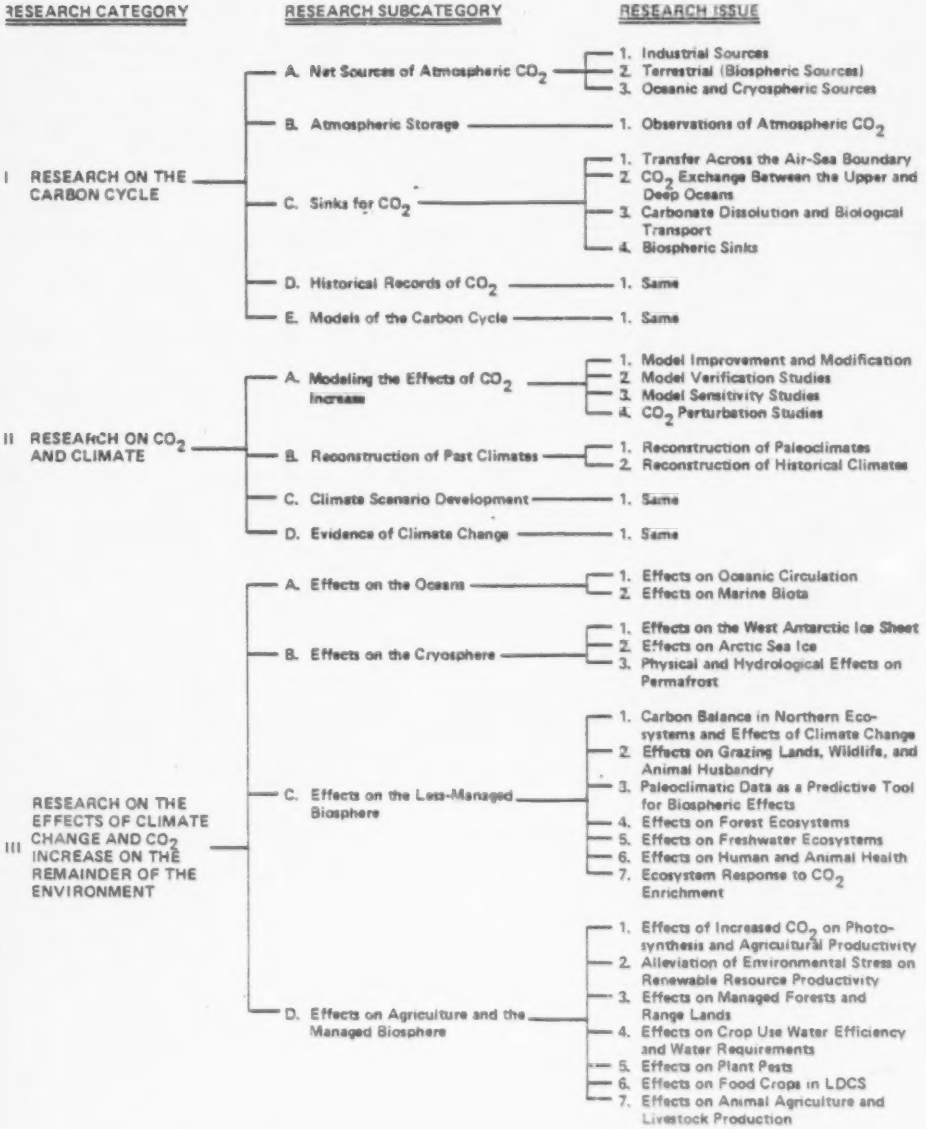
RESEARCH CATEGORY
RESEARCH SUBCATEGORY
RESEARCH ISSUE
I RESEARCH ON THE CARBON CYCLE
A. Net Sources of Atmospheric CO_2
1. Industrial Sources
2. Terrestrial (Biospheric Sources)
3. Oceanic and Cryospheric Sources
B. Atmospheric Storage
1. Observations of Atmospheric CO_2
C. Sinks for CO_2
1. Transfer Across the Air-Sea Boundary
2. CO_2 Exchange Between the Upper and Deep Oceans
3. Carbonate Dissolution and Biological Transport
4. Biospheric Sinks
D. Historical Records of CO_2
1. Same
E. Models of the Carbon Cycle
1. Same
II RESEARCH ON CO_2 AND CLIMATE
A. Modeling the Effects of CO_2 Increase
1. Model Improvement and Modification
2. Model Verification Studies
3. Model Sensitivity Studies
4. CO_2 Perturbation Studies
B. Reconstruction of Past Climates
1. Reconstruction of Paleoclimates
2. Reconstruction of Historical Climates
C. Climate Scenario Development
1. Same
D. Evidence of Climate Change
1. Same
III RESEARCH ON THE EFFECTS OF CLIMATE CHANGE AND CO_2 INCREASE ON THE REMAINDER OF THE ENVIRONMENT
A. Effects on the Oceans
1. Effects on Oceanic Circulation
2. Effects on Marine Biota
B. Effects on the Cryosphere
1. Effects on the West Antarctic Ice Sheet
2. Effects on Arctic Sea Ice
3. Physical and Hydrological Effects on Permafrost
C. Effects on the Less-Managed Biosphere
1. Carbon Balance in Northern Ecosystems and Effects of Climate Change
2. Effects on Grazing Lands, Wildlife, and Animal Husbandry
3. Paleoclimatic Data as a Predictive Tool for Biospheric Effects
4. Effects on Forest Ecosystems
5. Effects on Freshwater Ecosystems
6. Effects on Human and Animal Health
7. Ecosystem Response to CO_2 Enrichment
D. Effects on Agriculture and the Managed Biosphere
1. Effects of Increased CO_2 on Photosynthesis and Agricultural Productivity
2. Alleviation of Environmental Stress on Renewable Resource Productivity
3. Effects on Managed Forests and Range Lands
4. Effects on Crop Use Water Efficiency and Water Requirements
5. Effects on Plant Pests
6. Effects on Food Crops in LDCS
7. Effects on Animal Agriculture and Livestock Production

Table 6.—A National Program on carbon dioxide, environment, and society (con.)

	RESEARCH CATEGORY	RESEARCH SUBCATEGORY	RESEARCH ISSUE
IV	RESEARCH ON SOCIAL, POLITICAL, AND ECONOMIC COSTS AND/OR BENEFITS OF GLOBAL ENVIRONMENTAL CHANGE	A. Social and Institutional Responses	1. Cultural Determinants of Perceptions of Climate Change and Social System Reactions
			2. Climate Change, International Law, and Institutions
			3. Factors Affecting Vulnerability of Society to Environmental Change
			4. Political and Institutional Decision-Making in Response to Climate Change
			5. Perceptions of and Reactions to Environmental Change in Relation to Decision-Making
			6. Historical Dimensions of Effects of Climate on Human Societies
		B. Economic and Geopolitical Consequences	1. Economic Policy Evaluations of CO_2 Abatement
			2. Assessment and Resolution of Climate-Induced Strains on the International Economic System
			3. Mitigating Losses From Disruptions Caused by Environmental Change
			4. Planning for Environmental Change: Scenario Construction and Evaluation
V	RESEARCH ON THE AMELIORATION OF GLOBAL AND SECTORAL IMPACTS	A. Preventative Measures	1. Same
		B. Curative Measures	1. Same
		C. Moderating Measures	1. Same
		D. Adaptive Measures	1. Same
VI	REVIEW, INTEGRATION, AND EVALUATION (ASSESSMENT)	A. The 1984 Review, Integration, & Evaluation (Assessment) Report	1. Same
		B. CO_2 Information and Data System	1. Same

FY 1982

- Complete feasibility test of remote methods for biomass measurement.
- Complete North Atlantic cruises and measurements of the Transient Tracers in the Ocean program.
- Make preliminary estimates of climate sensitivity available from coupled ocean/atmosphere general circulation models.
- Sponsor an international meeting on carbon dioxide, environment, and society with sections on research, assessment, policy development, and public outreach.

FY 1983

- Publish summary results for all program elements for use in 1984 program assessment.
- Publish report on future climate scenarios.
- Make systematic estimates of CO_2 climate effects, including regional and seasonal aspects, available from model calculations.
- Publish semiquantitative models of environmental system response to a climate system change and CO_2 increase.
- Publish documents dealing with strategy and policy options.

FY 1984

- Conduct major interim program assessment. Begin redirection, termination, and/or initiation of research on basis of assessment.

Options for future program development

(See also discussion of options in Chapter I.)

DOE's plan for CO_2 research and assessment is divided into six categories (table 6):

- Carbon Cycle.
- CO_2 and Climate (modeling, reconstruction of past climates, evidence of change).
- Effect of Climate Change and CO_2 Increases in the Environment (oceans, cryosphere, biosphere).
- Social, Political, and Economic Costs and/or Benefits of Global Environment Change.
- Amelioration of Global and Sectoral Impacts.
- Assessment.

Planning is well advanced and research well underway on the first two categories—carbon cycle and CO_2 and climate. The degree of implementation of the other research categories depends on future funding decisions. Funding of Research Categories III and IV (environmental and social, political and economic effects) will be possible in FY 1981 for the most important environmental and societal consequences of increasing CO_2 in time for the 1984 Review. The DOE CO_2 Program will spend about $10.3 million in FY 1981.

A vigorous effort will be required to predict the environmental and societal consequences of increased CO_2 in the context of alternate energy strategies and economic and political scenarios. Additional resources are necessary for planned studies in biogeochemical cycles to predict how the CO_2 will be divided among the various reservoirs (oceans, cryosphere, biosphere, atmosphere). Detailed estimates will be prepared as more specific research plans are developed and the people and institutions to carry out the work are identified. These additional activities may require annual funding up to $10 million.

2. Climate and world food production

Assessments of weather and climate impacts on national and world food production are needed to develop strategies to deal with variable world food supplies.

Need

The major causes of season-to-season variation in world food production are climate fluctuations and weather extremes. One region may have poor production conditions, while others enjoy abundant food production. Information about climate effects on world food production is needed to develop plans and make tactical decisions to stabilize world food stocks and supplies. The importance of achieving this stability increases each year as populations continue to increase, levels of food intake increase, and the costs of production rise.

The national and international interests of the United States require that the impact of climate on domestic and world food supplies be understood better and that this knowledge be used in developing rational approaches for managing global food supplies. Such approaches would involve the U.S. government, farms, agribusiness concerns and the fishing industry, and international agencies concerned with production, distribution, and use of world food supplies.

Research on the impacts of climate on crop production has been carried out for many years, mostly on experimental plots. Less has been done to identify and measure impacts on fisheries and livestock. Experience is limited in using climate information to help shape food policies. The proposed program will build on present capabilities to measure and apply information about the effects of climate on food production, and will augment these capabilities to use climate information more effectively in food policy decision making.

Concern about the effect of climate fluctuations on world food supplies has been expressed at several international conferences on food and climate. The United Nations Food and Agriculture Organization (FAO) has in recent years increased its efforts to monitor and report on world food production and climate conditions affecting production.

The World Climate Program, being planned by WMO in cooperation with the International Council of Scientific Unions (ICSU), the United Nations Environment Program (UNEP), and other international organizations, includes assessment of climate impact on food production. Considerable attention was given to this aspect of regional and global climate problems at the 1979 World Climate Conference.

These programs provide opportunities for the U.S.

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National Climate Program to cooperate with international food and climate activities. They also reflect a widespread sense of urgency and concern about food supplies, including conservation and management of natural resources used in food production. Further interaction with international organizations is highly desirable so as to plan the U.S. program to address both worldwide and national concerns.

Lead Agency

USDA is responsible for developing the Nation's food policies and estimating its food requirements and will serve as the lead agency for detailed planning and coordination of multiagency efforts. A basis for this effort exists in the following activities that can be expanded:

- USDA collects information on U.S. and foreign crops and livestock production and trade, assesses outlook and situation for agricultural supply and demand, and has responsibility for agricultural policy decisions and program operations.
- USDA and NOAA's National Weather Service (NWS) operate the Joint Agricultural Weather Facility (JAWF) to provide timely information and assessments of world weather conditions. This information is taken into account in the assessment of U.S. and world agricultural outlook and situation.
- USDA and NOAA/EDIS make crop yield modeling studies as part of the Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) conducted jointly with NASA, DOI, and AID.
- USDA and State agricultural experiment stations perform extensive research on agricultural production, including biological response of crops and animals to climate and reduction of adverse climate effects.
- NOAA's National Marine Fisheries Service (NMFS) conducts climate-related fisheries ecosystem modeling and research related to conservation and management of living marine resources, and also provides market outlook reports and statistical information on fishery catches and trade.

National Program

The National Program for this thrust has the following objectives:

- Increased understanding and improved measurement of climate impacts on all food-producing systems.
- Assessment of the impact of climatic fluctuations on national and world production and use; evaluation of strategies for dealing with variable food supplies stemming from climate fluctuations.
- Identifying and supplying climate data and information services that are needed for more efficient and stable food production and for the conservation and management of natural resources used in food production.

The program thrust will be developed and coordinated in accordance with the following guidelines:

- The primary purpose of these efforts is to determine needs and provide climate information for use in making decisions on the production, distribution and use of major U.S. and world grain crops, meat, and fish.
- The activities will include identification and measurement of climate impacts, interpretations of climate data and assessments, and evaluations of the usefulness of climate data and impacts to support food policy decision making.
- Maximum use will be made of available climate information capabilities and products of ongoing research and applications.
- Plans will be coordinated, to the extent feasible, with related plans and applications of other countries and international agencies.

These guidelines may be revised and expanded as the thrust is planned, or as options for future work are developed in detail. Initial efforts will be planned around ongoing work in USDA and NOAA described above.

In addition to this USDA and NOAA work, recent studies by USDA, the National Defense University, DOT, and EPA have produced methods for analyzing the economic consequences of climate impact on food producing systems. The experience gained from these studies is especially useful as a base for developing and testing climate assessment methods that are relevant to policy issues.

USDA base funding related to climate impacts on food production in FY 1980 is estimated at $5.9 million and is projected to remain at that level through FY 1984. This includes climate impacts research and use of climate information by USDA-funded climate impact research at State agricultural experiment stations. NOAA funding for FY 1980 is estimated at $1.4 million and is projected to remain at that level through FY 1984. NOAA base program funding includes climate/crop yield modeling and climate impact assessments by the Environmental Data and Information Service (EDIS), and climate-related research in fishery oceanography by NMFS.

Milestones

FY 1980

- Form interdepartmental management and planning team to direct studies leading to development of detailed management and technical plans, including program options for FY 82 and beyond.
- Define climate information requirements and associated analytic capabilities required to support assessments of U.S. and world food.

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- Evaluate adequacy of ongoing activities and available resources and capabilities for meeting assessment and research and development requirements.
- Identify critical research and development needs for measuring climate effects on food producing systems (crops, livestock, and fisheries), and assessing impacts on aggregate food production.
- Identify research and development needed to improve the adaptability of food producing systems to climate conditions.

FY 1981

- Implement management structure to plan and coordinate climate and world food production activities.
- Carry out requirements studies and technical planning for optional activities, and prepare required multiyear budget plan and specific budget requests.

FY 1982

- Continue ongoing activities in support of U.S. and world food assessments.
- Carry out additional requirements studies and technical planning for future program options.

FY 1982/83

- Initiate work on one or more optional program efforts.

FY 1984

- Make application tests of available food and climate products and capabilities.

Options for future program development

(See also discusssion of options in Chapter I.)

USDA base resources, including technical plans and funds for the 5-year, multiagency AgRISTARS project beginning in FY 1980, appear adequate for improving significantly assessments of climate impacts on the world's major grain crops. A similar capability for assessing climate impacts on marine fisheries or livestock production does not exist now. It would require additional resources for research on fish and animal biological response to climate, for developing and testing operational uses of this knowledge, and for planning an integrated program.

Optional activities designed to improve understanding and response of marine and livestock production systems to climate effects would probably include the following:

Marine Fisheries

- Quantify and model effects of environmental factors on recruitment in selected fisheries off southeastern U.S. coasts.
- Intensify development of modeling techniques, including ecosystem interaction, for quantitatively assessing key fisheries of the Georges Bank and other waters off the northeastern United States.
- Systematically evaluate effects of climate fluctuations on the distribution and abundance of eastern Pacific Ocean fishery resources.

Livestock Production

- Model animal biological response to climate and related environmental factors in terms of animal growth, mortality, and reproduction.
- Develop management and decision models to assess the impact of climate on livestock production, shipping, and health.
- Test applicability of management and livestock models for reducing livestock losses due to adverse climate.
- Analyze the economic impact of climate extremes on the livestock industry, and meat prices and supplies.

It is estimated that these activities could be pursued with funding of $1 to $1.5 million annually.

B. Areas of Program Concern

1. Climate-related hazards

A recent estimate of damages resulting from climate-related natural hazards—such as avalanches, landslides and mudflows, accelerated coastal erosion, droughts, floods, lightning, hail and frost damages, hurricanes, tornadoes, windstorms, and urban snow—indicated that U.S. losses average nearly 600 lives and $5 billion annually. These hazards cannot be avoided completely nor would their prediction eliminate the associated losses. But an improved capacity to anticipate and respond to these events would reduce their adverse impacts significantly. Careful anticipation and more informed planning can enable us to avoid increased risks and capitalize on opportunities for reducing them. Increased knowledge about the processes and driving mechanisms of climate-related natural hazards is a prerequisite for more effective assessment and mitigation of the risks they pose.

In response to several storm-related disasters, the Federal government has become increasingly active in climate-related natural hazards research and planning efforts. The USDA, for example, has programs to investigate and monitor avalanche potential, drought, floods, and wind erosion. Similarly, DOD, through the Army Corps of Engineers, is analyzing flood and coastal erosion hazards. NOAA, in DOC, monitors significant weather events, and is responsible for issuing severe weather warnings and recommending evacuation. It also maintains a data file on all types of hazard events. NSF suports research and information dissemination on natural hazards and the social response to such hazards. The NSF-supported Institute of Behavioral Sciences at the University of Colorado has been a focal point of developmental work in hazard analysis. The Institute also maintains a Natural Hazards Research and Applications Information Center to facilitate the use of information on all phases of natural hazards work and initiates special conferences and symposia.

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Another important facet of the Federal effort resides in the Federal Emergency Management Agency (FEMA). In addition to studying all types of natural hazards, FEMA is responsible for coordinating emergency warnings and post-disaster assessments and assistance. Finally, DOI has one of the larger efforts in hazards research. Within the Water and Power Resources Agency, Office of Water Research and Technology, and primarily within the U.S. Geological Survey (USGS), data are collected, analyzed, and filed on a number of climate-related geophysical hazards. In addition, USGS is involved in studies of societal response to hazards in support of its mandate to issue public notices or other information releases concerning geophysical hazards.

Working from these established operations, activities planned as part of this Area of Program Concern include:

- Continuation of site-specific studies delimiting areas of hazard potential. USGS will maintain a strong role in this activity, working with NOAA and the Army Corps of Engineers.
- Continued research into the mechanics of natural hazard processes. The work of USGS on landslides, mudflows, coastal erosion, floods, and avalanches will be complemented by NOAA's work on hurricanes, tornadoes, windstorms, and lightning, and by the Corps of Engineers' work on hydraulic processes.
- Continuation of efforts to understand the societal implications of natural hazards and the societal response to hazard events and information. Leadership for this will continue to come from the NSF-supported Institute of Behavioral Sciences as well as USGS. This activity will also include further development of hazard assessment techniques and planning assistance/technology transfer functions.
- Maintenance and improvement of the public hazard notification and disaster assistance network. USGS will continue issuing notices of geophysical hazards, NOAA will provide severe storm and flood notices, and FEMA will continue providing pre- and postdisaster assistance and relief.

In addition, two activities constitute significant opportunities in the area of hazard mitigation which should receive careful evaluation.

Natural hazards research necessitates development and use of methods and equipment for locating and predicting hazards. USGS and NOAA currently use remote-sensing data in their operations, and improvement of such techniques is essential if advances in hazard prediction are to be achieved. In addition to expanding the applications of current spacecraft systems, special emphasis should be given to greater use of future systems in hazards research.

A key component in disaster mitigation is an aware and responsive citizenry. Through FEMA, NSF, NOAA, and DOI, a much broader and more comprehensive program should be instituted to promote public awareness and education in natural hazards, especially in zones of high hazard potential.

2. Energy production, distribution, and demand

The droughts and extreme cold spells of recent years have increased our awareness of weather and climate fluctuations. There are identifiable climate effects on energy resource extraction, transportation, generation, distribution, and use. Severe winter storms interfere with the mining and transportation of coal. Hurricanes result in loss of natural gas production from Gulf Coast wells. Energy distribution problems result from storms and floods, and increased energy demand and use occur during heat spells, cold snaps, and droughts. Better planning for these recurring events and reduction of their impact depend upon better measures of the relationship of weather and climate to energy production, distribution, and demand. To use predictive information, it will be necessary to understand the impact of weather and climate on energy systems.

Recognizing that there is a relation between weather and climate and energy demand is simple. Quantifying that relation is more difficult. It is even more difficult to develop systems that use climate information to make decisions on fuel allocation and storage, design efficient distribution systems, develop energy conservation strategies, or evaluate those strategies—yet progress has been made. For example, procedures now exist for considering 30-day and seasonal climate outlooks in managing primary and alternate fuel supplies. Better quantitative assessments of the effects of climatic fluctutions on the demand for different fuels are needed. Structuring of climate information to make it more readily adaptable to these applications is essential. These activities require close collaboration between DOE and NOAA's Climate Analysis Center and Center for Environmental Assessment Services.

Fuel demand models have been developed for a small number of discrete locations (Greeley, Colo.; Cheyenne, Wyo.; and Minneapolis, Minn.). Efforts are underway to modify the models to operate in real time and to extend the area coverage. These efforts could be accelerated to provide a set of regional fuel-demand models covering all areas of the country in 3 years at a total cost of about $0.5 million.

The impact of climate on the production of energy has been studied in considerable detail and in some cases is well understood. In the case of hydroelectric power generation, for example, the dependence of system design and operation on climate data is widely recognized. The operation of fossil fuel systems is generally less dependent on meteorological conditions, but the climatology of air pollution is a major factor to be considered in plant location, design, and operation. Suitable strategies must be designed for sharing loads or switching fuels in order to maintain power supplies while meeting air quality standards during extreme events of air stagnation. This is an even more critical problem with increased dependence on coal.

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Some "alternative" energy sources—wind, Sun, and ocean waves, currents and thermal stratification—depend even more critically on climate. Climate determines their availability and is often a major factor in the efficiency of the conversion system. For example, widespread use of solar energy depends on being able to accommodate to intervals of cloudiness, high and low temperatures, and humidity. Wind generation systems must be designed to be efficient under normal wind conditions and to withstand high winds, but they often must be located at sites for which adequate data are not available. For all these systems, specific data needs and interpretations will be developed by particular designers or users (e.g., DOE, NASA, HUD, and NOAA).

Present plans call for the 1981 DOE effort to assess impacts of climate perturbations on the energy system to be funded at just under $400K. Possible additional efforts should deal with impacts on various components of the nuclear as well as the fossil fuel cycle, with a wide variety of geographical areas characterized by both climatic and socioeconomic differences, and with a wide range of alternative energy sources. To exercise this option, funding for FY 1982 of about $1 million would be needed. The full scope of this activity could require doubling the initial funding.

3. Impact assessment methodologies

A major goal of the National Climate Program is to assist policy-making officials and other decision makers in anticipating and responding to the social, political, and economic implications of climate variations and changes. This requires assessment processes in a broad range of national interest areas cited by the National Climate Program Act—natural environment, agricultural production, energy supply and demand, water resources, transportation, human health, and national security.

Several cooperative projects have demonstrated the feasibility of assessing climate impacts in certain limited contexts. They include the Large Area Crop Inventory Experiment (LACIE), a joint NOAA/NASA/USDA effort; the Climate Monitoring and Early Warning for Disaster Assistance Needs in Developing Countries Program, a cooperative State Department/ NOAA program; and the initial energy demand estimation programs conducted jointly by NOAA and DOE.

But it is a long step from assessing the impact of climatic fluctuation on the yields of a few key crops to predicting how global climate will affect world food supplies, prices, and international trade. There are major differences between determining how regional climate anomalies will affect local energy demand and water supplies and estimating national and international economic and social impacts of worldwide climate variations. Consequently, much remains to be done to establish valid and credible methods for assessing the comprehensive impacts of climate fluctuations.

In 1980, the National Climate Program Office (NCPO) held a workshop on climate impact assessment methodologies to begin establishing a interdisciplinary process and research agenda. NCPO has lead responsibility for following up recommendations resulting from the workshop. Mission agencies have responsibility for identifying specific climate-related policy issues and problems that need methodological assistance. Much of the methodology development work that will be undertaken will be directly applicable to high priority climate impact assessments—energy, water resources, arid and semiarid lands, and especially CO_2 and world food production. NCPO will identify complementary efforts among agencies in these priority areas. EPA has very relevant experience from its studies of the effects of regulatory actions.

Recent international developments with regard to the establishment of a World Climate Program will facilitate close coordination with research plans and activities in other nations and early development of suitable interdisciplinary approaches to climate impact assessment.

4. Regional climate effects of humans

Human activities can cause changes in the Earth's albedo, or surface reflectance, in the Earth's surface roughness, and in the air's composition. Some changes could lead to climatic effects on a regional (100-3,000 km) scale.

While regional climate changes have certainly occurred, there is no well-documented regional—or global—climate change for which human activity is clearly the cause. Acid rain is a regional environmental problem, but it has not been shown to be associated with climatic change. There are suggestions that deforestation of temperate regions in Europe and North America and overgrazing in semiarid regons, which resulted in their desertification, have changed the albedo over the past few thousand years. Several theoretical analyses conclude that albedo changes could cause changes in temperature or other climatic characteristics. It also has been suggested that continued deforestation of equatorial forests might lead to regional climate changes. Further research on albedo changes and their climatic consequences is warranted.

Several effects may occur together. Windblown Saharan dust travels across the Atlantic Ocean, and studies have shown that this dust plays a role in atmospheric radiative transfer. The dust from the Rajasthan Desert of India reaches higher than 5 km, and it, too, disturbs the radiative balance. Some of the dust may result from overgrazing, which has also altered the local surface albedo.

Significant increases in surface mining and processing of coal and shale in the western United States will likely cause significant additions to regional dust loadings. These could, in turn, affect climate. Documentation of present dust levels and distribution should be undertaken soon, and the radiative and nucleating properties of the dust should be evaluated. In addition, the presence of strongly absorbing carbonaceous particles, believed to originate in industrial combustion, can enhance the low-level warming due to global "greenhouse" gases. Here, too, more study is warranted.

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The most prominent human-caused change to the atmosphere is an increase in its aerosol content, stemming from aerosols injected directly (e.g., dust, ash) or from those produced from gas-to-particle conversions (e.g., sulfates from SO_x emissions, nitrates from NO_x emissions). These additional particles could disturb the natural radiative balance in the air and affect cloudiness and precipitation regimes.

Industrial effluents may affect clouds and precipitation. However, it is difficult to distinguish the effects of particles from human sources from those of natural substances, and the evidence gathered thus far is inconclusive. Negative findings in some studies of certain substances do not rule out other existing or future pollution emissions as possible influences on weather or climate. As a general rule, anomalies in observed precipitation patterns that are apparently attributable to air pollution must be examined with the utmost caution.

Many particles observed on a regional and even global scale derive from gaseous sulfur compounds. Their quantity is likely to increase as coal usage increases. There is also a continued increase in the release of oxides of nitrogen (NO_x) from powerplants and transportation systems. Studies in both areas should be augmented, particularly on the quasi-gaseous and liquid forms of atmospheric nitrates.

One regional climate effect that requires attention is Arctic haze. Much, if not all, of the tropospheric air over the Arctic basin contains many particles, primarily sulfates, in the late winter and spring. As a result, visibility is reduced and turbidity is raised during that period. This haze plays a role in the climate of the Arctic. Trajectory and wind analyses suggest that the origins of the particles are industrial sources in western Europe and parts of the Soviet Union. However, while human sources are now blamed for the recent Arctic haze, greatly reduced visibility due to haze in the Arctic was reported even before the industrial explosion expansion that followed World War II. Thus doubts still linger about how much of the Arctic haze is of human origin.

The issue is important as it may lead to suggestions for additional constraints on industrial activity. The Arctic is an area of particular climatic sensitivity, and regional effects in the Arctic may lead to more extensive climatic responses. Further chemical and physical characterization of the haze particles and analyses of air trajectories are needed to settle the issue of the origin (human vs. natural) of the haze. To determine its impact on climate, a concerted effort to measure and model the difference in polar radiative balance with and without the haze is the single most important research need. There would likely be a considerable willingness to cooperate in such an effort on the part of the Scandinavian countries, but the cooperation of the Soviet Union would be welcome. A budget of about $2 to $3 million per year over 5 years would be required for such a program.

The National Climate Program Office, working with other interested Federal agencies, such as DOE (concerned about the effects of coal and shale mining and processing), USDA (concerned about deforestation), and EPA (concerned about air quality), will seek to identify regional climatic effects of humans, and conduct research to understand any cause-and-effect relationships.

5. Semiarid and arid lands

Climate is a crucial factor in the management of semiarid and arid lands. Dry-land ecosystems exist in a delicate balance with climate and are very sensitive to overuse or mismanagement. A long-standing major use of semiarid and arid lands is for grazing domestic livestock and wildlife. Other more recent activities include strip mining and recreation (e.g., off-road vehicles). Because of the limited flora and fauna and harsh conditions in arid and semiarid regions, their ecosystems are often slow or unable to recover from massive disturbances of the land surface.

Only a relatively small part of these lands has the water supplies, soil conditions, and terrain required for irrigation development. Increased human activities can amplify the stresses imposed by climatic variations and lead to severe damage and permanent degradation. Developing effective land management strategies for the arid and semiarid regions requires a better understanding of climate and its complex interaction with land use and natural systems.

The interaction of human activities, climatic events, and other natural factors can impose such stresses on dry land ecosystems that they collapse, leaving desertlike conditions. The Sahelian drought of the early 1970s demonstrated the tragic and massive economic and social impacts of desertification, and this sequence of events spurred the United Nations to develop a plan to understand and combat spreading worldwide desertification.

Responsibility for Federal programs concerned with arid and semiarid lands resides mainly with DOI and USDA. Each department manages vast areas of public land in the 17 western States. DOI is leading a national effort, involving Federal agencies, States, and private organizations, to prepare a National Plan of Action To Combat Desertification (NPACD), as part of the United Nations' desertification control effort. In addition, the United States and Mexico have agreed to cooperate in improving the management of arid and semiarid lands. Both DOI and USDA conduct research related to irrigation, land reclamation, soil and water conservation, forest and rangeland management, and maintenance of wildlife habitats. Other Federal programs related to arid and semiarid lands include EPA and DOE efforts to reclaim strip-mined lands, DOD's management of large military reservations in the arid west, and NSF-supported arid lands research.

The Climate Program has significant opportunities to help assure that climate information appropriate for the management of arid lands is available and more effectively used:

- **Resource Attributes of Climate.** Improved methods are needed for measuring the effect of climate fluctuations and extremes on the produc-

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tivity of arid and semiarid lands. The need is urgent in the case of grazing lands. This land use contributes directly to food production and to the maintenance of an economic and related social structure. A capability to predict grazing land productivity under variable climate would aid in land use and livestock management by providing information for adjusting livestock numbers and for investing in appropriate land management practices. Another needed application of climate information is to support assessments of the Nation's renewable resources. These assessments do not, at present, sufficiently consider the effect of climatic variability on the output or carrying capacity of arid and semiarid lands.

One particular activity that the United States and Mexico could conduct, under their bilateral agreement to deal with desertification, would be the development of a climate and land use data base for arid lands research and management decisions.

- **Climate and arid land ecosystems.** Some land uses permanently change or even destroy arid land ecosystems. Actions to preserve or restore them must be based on improved understanding of the role of the climate variables. For instance, research to develop or locate new plant species for arid regions should include careful assessment of response to the climate of the areas considered.
- **Climate and cultural interaction.** Rapid demographic, economic and cultural change is occurring in arid and semiarid regions. At one extreme, agricultural displacement with attendant economic cost and social disruption often results from an extended drought. At the other extreme, arid climate can attract industrial and urban development. The opportunities and requirements should be explored for using climate information to help reduce costs, stresses, and risks associated with these changes.

6. Water resources management and planning

Water is a critical resource. Throughout history man has attempted to cope with irregularities in the availability of water. Ancient societies waxed and waned as the abundance and quality of water varied. Modern industrial societies are no less dependent on water, and today considerable sophistication is used in the design of structures and strategies to control water supplies and water quality in the light of what is known about climate. This strong link between hydrologic planning and climatology is even more crucial now:

- The rapid expansion of irrigation has imposed increased demands on ground water supplies, often at rates well in excess of recharges. This "mining" of ground water lowers the water tables and makes extraction more costly and energy-intensive. In some areas depletion of the ground water supplies threatens the collapse of regional economies.
- Many energy production options, such as oil-shale development, would place much greater demands on water resources, often in regions where water shortages are already a problem.
- Environmental and economic considerations limit the options available in the design of hydrologic facilities, fostering designs that are less resilient to climate change. This comes at a time when hydrologists are re-evaluating how best to deal with climatic factors in the analysis and design of hydrologic systems, and when there is growing recognition of the reality of natural and human-induced climate change.
- Reservoir sites are becoming difficult to find. Most acceptable locations are already developed, and present land owners strongly resist having their land taken for such purposes. This means that existing water management systms must be used more efficiently before additional development is justified.
- The California drought of 1976-78 was very severe, but the region and the Nation survived with relatively minor adverse consequences. In most cases, the management options chosen turned out to be wise ones. If the drought had continued through a third winter, however, much more drastic consequences probably would have ensued. This points out the nationwide need to use the best possible climate information in the development and the implementation of water contingency plans.

The responsibility for water resource systems design and management is distributed among a large number of Federal, State, and local agencies. Among Federal agencies that manage or plan for water resource systems are USDA's Soil Conservation Service and Forest Service, the U.S. Army Corps of Engineers, EPA, and in DOI's Water and Power Resources Agency, Bureau of Land Management, and Water Resources Council. In addition, important hydrologic expertise exists in DOI's USGS, DOC's NOAA, and State water resource institutes. All recognize that climate is a key element in the planning and operation of water management systems. There are, however, differences about how to deal with questions of climate and climate change and how to use climate information as a mangement tool. A growing need is emerging for short-range (several months) predictions of climate variables for operational decisions by water users and managers. The concern of the Climate Program is to assure that climate data and information needed for management and design decisions are available, and that a better use of knowledge

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of climate is incorporated into such decisions. Three studies are planned in FY 1980 and FY 1981 that will shed light in this area.

One study will investigate design and operation strategies for water resource systems that can accommodate uncertainties in climate parameters.

Another study will be commissioned to examine how the various agencies' hydrologic models deal with climate change, how sensitive the design parameters are to climate change, and what information about climate and climate change is most important for the analyses.

Several climate-related tasks will be added to an extensive ongoing water resources/economic development effort to investigate the importance and use of climate information in a specific context. Discussions have already begun with DOC's Economic Development Administration in connection with their study of future development of the Ogallala Aquifer. The kinds of questions that would be raised are:

- How could now-available climate information best be used to assure more efficient use of water resources?
- Are there more useful types of information that could be made available?
- How much could future demands on the system be reduced through use of climate information that might be available in, say, 30 years—for example, improved seasonal predictions of regional precipitation?
- How are plans and designs affected by different judgments about the future course of climate, either as discernible from interpretations of past records or in response to considerations of human-induced changes?

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Mr. SCHEUER. Thank you very much.

What road do you think the EPA, which, of course, is also subject to the oversight jurisdiction of this committee, ought to be playing in this whole CO_2 grand design?

Mr. BELSKY. They are going through a process of deciding what kind of research and development they should do in order to adequately prepare regulations. That is their responsibility—to prepare regulations—but they have R&D responsibilities, so they can make regulations in a proper mode.

In the past, they have had a relatively small role in the CO_2 program and in the national climate program, in fact. They are increasing the R. & D. role. Ms. Gorsuch made a statement indicating she wishes the agency could be involved much more significantly in looking at "why", and "how", and "if", as a background to regulations, and I believe she is going to follow through.

We have had two sets of meetings with medium level people in the Environmental Protection Administration about their ideas to figure out what should be done.

They are putting together a miniplan which we also hope to have ready for this meeting in September to present as part of an interagency effort. Their role seems to be in part to say what should be the response to what we believe are the threats.

That is the mandate. How they are going to implement that, I think, is one of the things we will look to them for. If regulations are necessary, their responsibility and mission is to draft regulations, but their mission is also to say, especially under the new regulatory order of the administration, when regulations are not necessary. In order to do that, they have to have the basic information to make this decision.

Mr. SCHEUER. You were discussing their budget and the allocation of their $14 million budget among these six different categories. Do you generally agree with the program balance that has been spelled out in the red book in terms of the social, economic and political implications of CO_2? We haven't got the hard data and won't get it until October, but we have a certain sense of disquiet and concern that they may be subtantially downgrading the components of social, economic and political impact of CO_2 on long-range public policy decisionmaking.

Mr. BELSKY. I have a different role than does the Department of Energy. I have the role as the Acting Director of the national office to look at the national program rather than the DOE.

From the national program perspective—I think the red book presented a fairly comprehensive and balanced point of view. That may not be the DOE perspective of different missions. That is the problem in any interagency situation in which the national program has to look to the various agencies to put together the best package. What they decide to do has to be taken into account by the other agencies in putting together the comprehensive program.

Mr. SCHEUER. Your mission is national. Do you get any inputs from the Department of State, for example, on the international implications of climate change?

Mr. BELSKY. In working with the Department of State on the international aspects of the national climate program, which is

now primarily focused on the world climate program, the major role, we believe, of the national climate program is to work with the other nations and, as you indicated very strongly, Mr. Chairman, take a comprehensive coordinating holistic approach to these issues, and we believe the only way that can be done is to have a comprehensive holistic approach as to the world climate program.

The State Department is working very closely with the national climate program and with the Federal agencies, in seeking to give the kind of assistance to the world climate program that will make it work.

Yes, they have been contributing to that effort. They are a member of the program board—not just the program board of the climate program generally, but of the CO_2 climate program board as well.

Mr. SCHEUER. Thank you very much for your patience and very interesting and informative testimony.

The hearing is suspended at the wish of the Chair.

[Whereupon, at 2:48 p.m., the subcommittees adjourned, to reconvene at the call of the Chair.]

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